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RESULTS OF ENTRAINMENT AND IMPINGEMENT STUDIES CONDUCTED AT THE BRAIDWOOD NUCLEAR STATION AND THE ADJACENT KANKAKEE RIVER

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EXECUTIVE SUMMARY

A study was conducted to assess the environmental effects of the intake structure at the Braidwood Station, located on the Kankakee River. Major components of the 316(b) study included larval fish and macroinvertebrate sampling at four locations (plant intake, plant discharge, Kankakee River, and Horse Creek) during the period April to September 1988, larval fish survival studies at the plant's intake and discharge, and a one-year impingement study, which started in October 1988. Important findings were:

ENTRAINMENT

Fish

A total of 7197 larvae and 271 eggs were found in the 264 samples collected at the Intake. Densities were highest during the period 10 May to 28 June. Throughout the study, densities were much higher at night than during the day. Taxonomically, the intake larval collections were dominated by minnows (excluding carp) - 38%, carp - 17%, suckers - 15%, and Percina spp. - 14%.

The 406 Kankakee River samples yielded 2590 larvae but only 41 eggs. Densities were highest during the period 24 May to 7 June. Densities at night averaged three times higher than during the day. Taxonomically, the river samples were dominated by suckers - 33%, minnows (excluding carp) - 26%, and carp - 18%. No differences in the lateral (i.e., bank to bank) or vertical (i.e., within the water column) distribution of larvae were found.

Collections in Horse Creek yielded 7087 larvae and 89 eggs from 136 samples. Densities were very high in late May and early June, the period corresponding to the peak drift of sucker larvae. Densities at night were more than 60-fold higher than during the day. Taxonomically, the Horse Creek samples were dominated by suckers - 73% and minnows (excluding carp) - 15%.

Collections at the Discharge yielded 631 larvae and 182 eggs. Peak densities occurred during the period 17-24 May. Densities at night were about twice as high as during the day. Taxonomically, the composition of fish at the Discharge was much different than at any of the other sites, being dominated by gizzard shad - 39% and Pomoxis spp. - 33%.

Macroinvertebrates

A total of 23,509 macroinvertebrates representing 161 taxa were found in the 194 drift samples analyzed during the study. The breakdown by location was as follows:

	Intake	River	Horse Creek	Discharge
No. of Taxa	121	132	107	61
No. of Organisms	7190	13,056	1612	1651

The drift in the river was dominated by mayflies - 59% and midges - 17%. At the Intake, the dominant organisms were mayflies - 46%, midges - 23%, and naidid worms - 13%. In Horse Creek, the dominant organisms were midges - 29%, naidid worms - 22%, mayflies - 18%, and the amphipod Hyalella azteca - 10%. In the Discharge, the dominant organisms were midges - 59%, caddisflies - 20%, and mayflies - 10%.

Survival

For three studies combined, 68% of the larvae survived passage from the river screenhouse to the one acre holding pond. Among taxa collected frequently, Lepomis spp. had a survival rate of 78% while minnows exhibited 60% survival. At the Discharge, the rate of survival for all taxa combined was 75%, largely the result of 80% survival for Lepomis spp., the dominant taxa collected.

Impact Assessment

Extrapolations of the entrainment data yielded the following estimates:

	Actual Case	Worst Case
Fish eggs	0.7 million	1.0 million
Fish larvae	5.8 million	11.2 million
Macroinvertebrates	50.3 million	123.8 million

Based on the estimated number of each of these groups in the Kankakee River, the Braidwood Station entrains 84-122% of the fish eggs in the river, 17-29 percent of the fish larvae, and 8-19 percent of the macroinvertebrates depending on whether actual or worst case estimates are used.

The percentage of eggs entrained is anomalously high, either as the result of spawning taking place near the Intake or other unknown factors. It was determined that impacts to fish were unlikely when entrainment losses were considered in relation to fish populations throughout the Kankakee River. However, impacts to local populations are possible, particularly to darters. Field data collected in 1989, however, has not revealed any impacts to the local fish fauna.

River flows during the period when most of the larvae were entrained (i.e., May-July) were well below historical norms and constituted worst case conditions. Since the station would take in a much smaller percentage of the river flow under normal flow conditions, impacts are much less likely during normal flows than under the worst case conditions that prevailed in 1988.

Based on the lower percentage of the population affected, impacts to macroinvertebrates are less likely than those to fish.

IMPINGEMENT

The year long impingement study resulted in the collection of 59 species and 17,680 individuals. Gizzard shad dominated the catch (69%), with rock bass (10%), smallmouth bass (3%) and longear sunfish (3%) also being well represented. In terms of biomass, gizzard shad accounted for 63% of the total, followed by rock bass (9%), smallmouth bass (4%), and carp (3%). Most of the rock bass and all of the smallmouth bass were young-of-the-year or juveniles. Impingement rates were much higher during fall, winter, and spring than during the summer. Highest rates occurred in late December and early January.

Extrapolation of the data to the entire study period resulted in total impingement losses estimated to be 53,111 fish, including 36,608 (69%) gizzard shad, 5129 (10%) rock bass, and 1594 smallmouth bass (3%).

<u>Impact Assessment</u>

The loss of 53,000 fish will have a negligible impact on fish populations in the Kankakee River because:

(1) it is a small number compared to the total fish population in the river;
(2) more than two-thirds of this number is composed of gizzard shad;
(3) the estimated number of gizzard shad may be much higher than normal because of a particularly high population of this species in the river prior to the winter of 1988-89;
(4) of the game fish collected, almost all were young-of-the-year or juveniles;

(5) no impacts were detected in either of the 1989 adult fish field studies conducted near the site; and

(6) some of the fish impinged and probably most of the gizzard shad were probably already in poor condition because of disease or various other stresses, particularly winter-induced stress and morality.

Two "listed" species were impinged; two river redhorse, which are classified by the IDOC as threatened, and 16 pallid shiners (chubs), which are classified as endangered. The impingement of two river redhorse, a species which is actually fairly common in the Kankakee River, is inconsequential to its population. Extrapolation of the pallid shiner (chub) data results in the estimated loss of 73 individuals of this species, all during the period 16 April to 10 June. Although field studies conducted by EA have shown the pallid shiner (chub) to be more common and widely distributed than previously thought, the estimated loss of 73 individuals may affect the portion of the population of this species near the Braidwood Station. Such an impact remains to be documented. Although impacts to the population near the Braidwood Station are possible, it is unlikely that these losses would significantly affect the populations that exist well upstream of the station, as these individuals probably breed in separate areas.

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1. INTRODUCTION

The Braidwood Generating Station is located near Godley, Illinois, approximately three miles southeast of the Kankakee River. The station consists of two nuclear powered generating units, each having an 1120 megawatt capability. The station design includes a 2,640 acre cooling pond. The source of make-up water for the cooling pond is the Kankakee River. The river screenhouse is located on the south bank of the Kankakee River approximately 0.5 miles downstream of Custer Park, Illinois. Water is pumped from the screenhouse to the cooling pond through an underground pipeline. In 1988, the generating station began commercial operation: on 29 July for Unit One and on 17 October for Unit Two. The Illinois Environmental Protection Agency required that an entrainment study and a one-year impingement monitoring study be conducted to evaluate the intake with respect to 316(b) requirements.

To address these requirements, an entrainment study was initiated in the spring of 1988 and an impingement study was initiated in the fall of 1988 in a small section of the Kankakee River and Horse Creek near Custer Park, Illinois (Figure 1-1). The purposes of these studies were to describe the drifting ichthyoplankton and macroinvertebrate populations, estimate the magnitude of entrainment of these populations at the Braidwood intake structure, and estimate impingement losses at the Braidwood Intake. Although commercial operation did not begin until July, pumping began in April to accommodate this study. Although the station was operating during the entire study period, the Intake was decoupled on 35 days during the period 8 July to 22 August (Table 1-1) to fulfill an agreement with the Illinois Department of Conservation (IDOC) not to withdraw water from the river during critical low-flow periods (Larimore and Peterson 1989). The discharge structure was operating during this period.

Baseline ichthyoplankton studies for the Braidwood Station have been conducted by Westinghouse (1973; 1975), Bergman (1978), Bergman and Hutton (1979) and Bergman et. al (1980), and include information on ichthyoplankton abundance, distribution, and occurrence as well as estimates of drift.

Specific objectives of the Braidwood entrainment study include:

1. Estimate fish egg and larvae entrainment at the Braidwood intake structure on the Kankakee River and the percent of larvae surviving the transit from the river to the cooling pond.

2. Estimate fish egg and larvae drift in the Kankakee River upstream of the Braidwood intake structure.

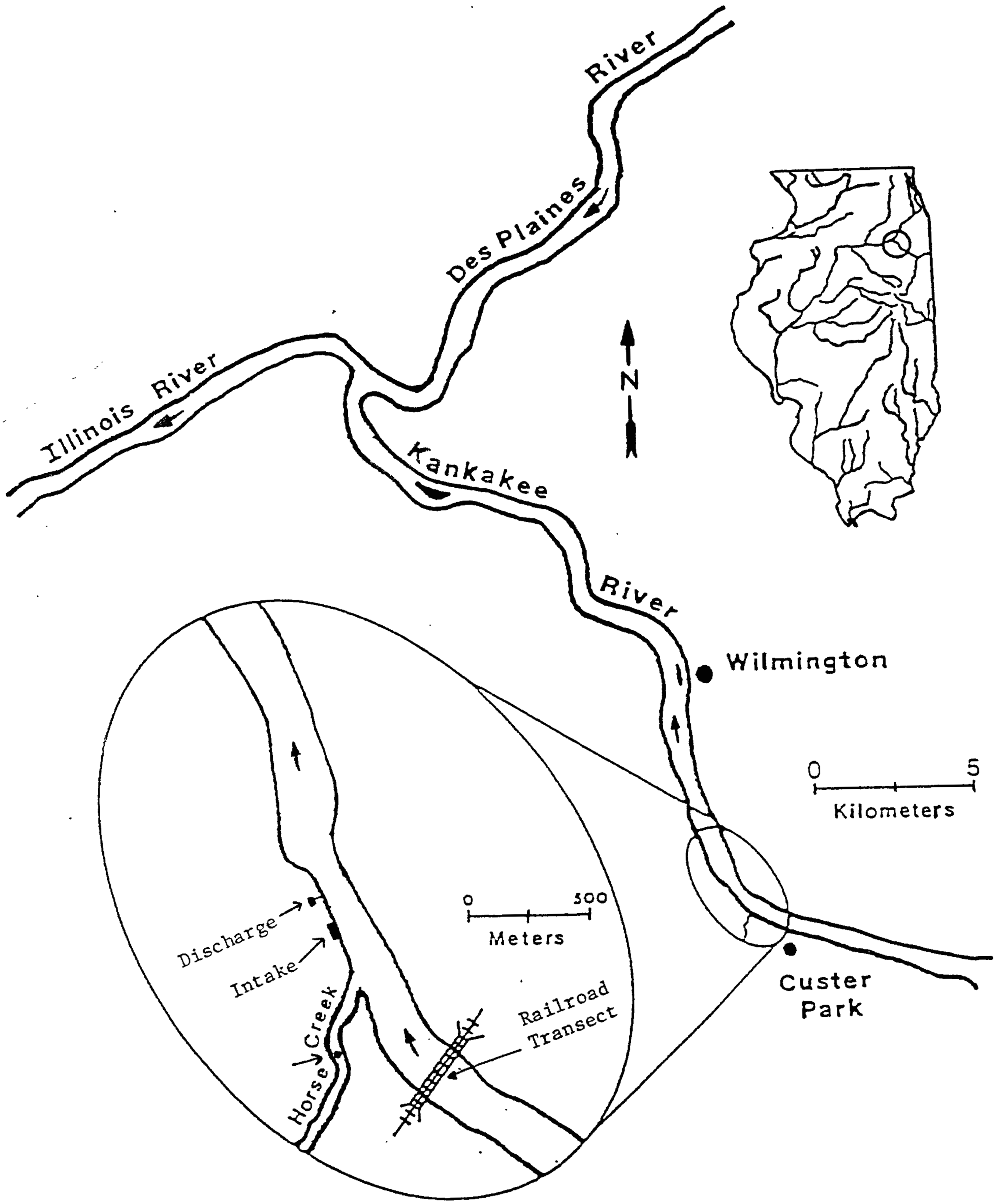


FIGURE 1-1. Locations of Sampling Sites during the Braidwood Station Entrainment and Impingement Studies, 1988-1989.

Revised from Larimore and Peterson 1989.

TABLE 1-1 DATES WHEN THE BRAIDWOOD GENERATING STATION WAS DECOUPLED FROM THE KANKAKEE RIVER DUE TO LOW WATER FLOWS DURING 1988

Not decoupled (pumping when needed, not limited by low water)	Decoupled	Pumping
Before 8 JUL	8-13 JUL	14-15 JUL
	16 JUL	17 JUL
	18 JUL	19 JUL
	20 JUL	21 JUL
	22 JUL-14 AUG	15-20 AUG
	21-22 AUG	
After 23 AUG		

Source: Larimore and Peterson 1989

3. Estimate fish egg and larvae abundance in the blowdown from the cooling pond at the Braidwood discharge structure into the Kankakee River and determine the percent of larvae surviving the transit from the cooling pond to the river.

4. Examine two hundred of the samples collected during the fish egg and larvae program to assess macroinvertebrate drift.

5. Assess the impact of the Braidwood Generating Station in terms of percent of the fish and macroinvertebrate drift populations entrained by the station.

A preliminary impingement study was conducted at the Braidwood Intake during the period December 1980 to February 1981 (CeCo 1981). The objectives of the current impingement study were:

1. Estimate fish impingement at the Braidwood intake.

2. Assess the impact(s) of this impingement on fish populations in the Kankakee River.

2. METHODS

2.1 ENTRAINMENT

2.1.1 FIELD PROCEDURES

Collections were made during both the night and day at four locations: the Kankakee River, the Braidwood intake, the Braidwood discharge, and Horse Creek. Night sampling was initiated no earlier than 0.5 h after sunset.

2.1.1.1 Kankakee River

Ichthyoplankton samples were collected on Tuesdays from 19 April to 13 September 1988 in the Kankakee River along a transect at the Norfolk and Western Railroad Bridge. Collections along the railroad bridge transect were made at four points (K1, K2, K3 and K4) (Figure 2-1). Location K1 was located near the right bank (facing downstream) and Location K4 was located near the left (plant side) shoreline. The railroad tressels were used as boundaries between locations. The sequence in which the points along the transect were sampled was randomly chosen each time. Two depths (surface and bottom) and two replicates per depth were sampled at each point, once during the day and again during the night over a 24-hour period. This resulted in the collection of 32 samples from the Kankakee River each week:

4 pts x 2 depths/pt x 2 reps/depth x 2 time periods = 32

Samples were taken using a conical plankton net (No. 0 mesh, [505 micron] 2.5 meters in length with a 0.5 meter diameter opening) attached to a 0.4 meter square frame. A plankton bucket was attached to the cod end of the net and a calibrated General Oceanics (GO) flow meter (Model 2030) was positioned in the center of the square frame. During collections at each location the boat was anchored in position and one surface and one bottom samples were collected simultaneously. The replicates were collected by repeating this procedure a second time. Nets remained in the water from 6 to 47 minutes, depending on current velocity. Times were adjusted to yield sample volumes of $40m^3$. Because net avoidance increases as velocity decreases, samples were not collected at velocities <0.2-0.3 ft/s. When shallow water (less than 0.85 m) prevented collecting the bottom samples, surface samples only were collected. During low flow periods, there was negligible current velocity at some points along the transect and/or at certain depths. When this occurred, no samples were collected from such areas. During periods when less than the scheduled number of samples were collected, velocities were typically documented and recorded using Marsh-McBirney current meter. Total depth at each location for each sampling date is presented in Table 2-1. Depth was variable among dates because areas of greatest velocity

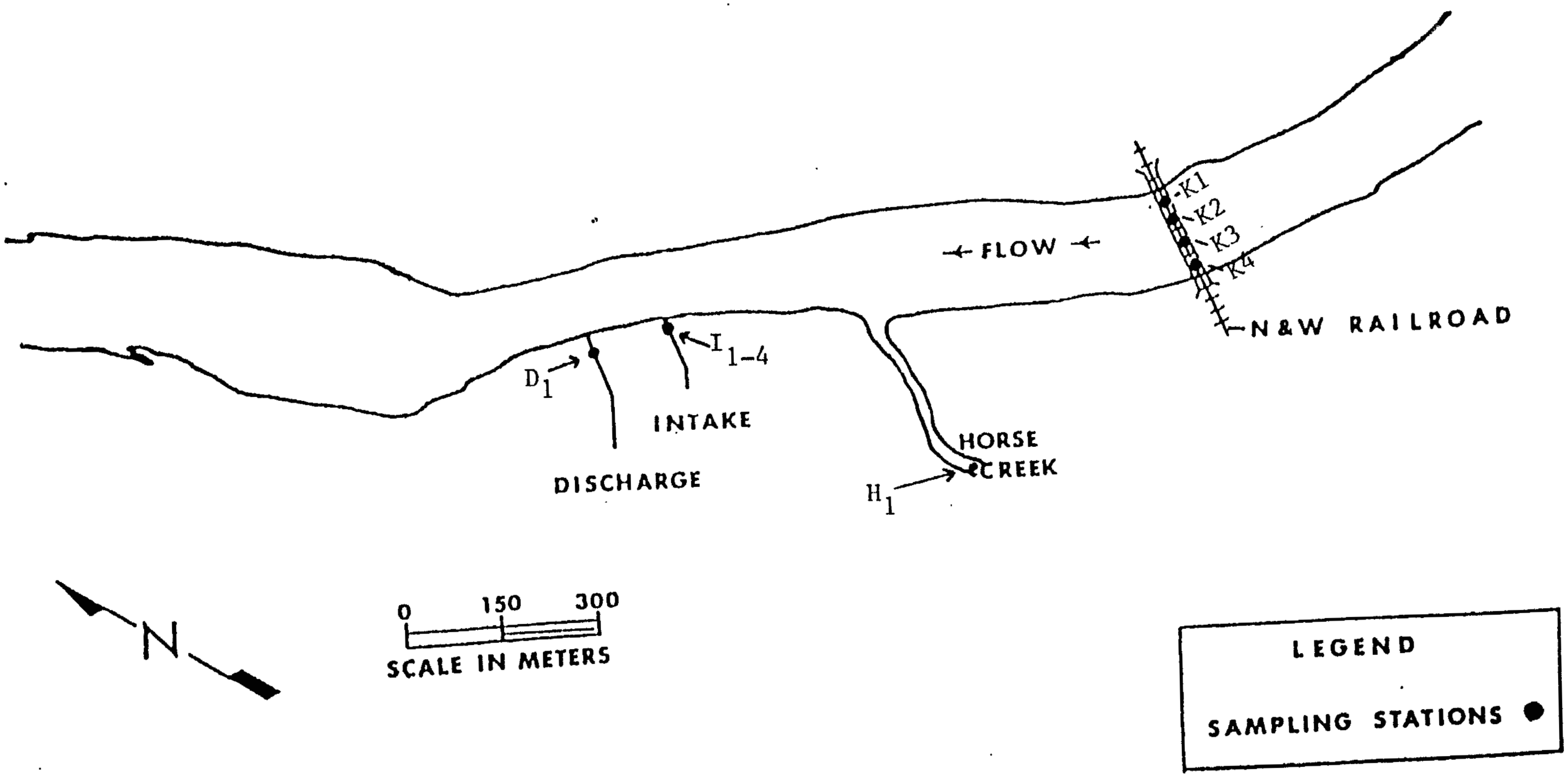


Figure 2-1. Sampling Locations in the Kankakee River, Horse Creek, Intake, and Discharge during Entrainment Studies, 1988.

Revised from Bergman et al. 1980.

were selected for sampling (Table 2-1). A bathymetric cross section showing the width and depth across the transect is presented in Figure 2-2.

All samples were preserved in the field with 10 percent formalin containing rose bengal and returned to the laboratory for processing and analysis. Of the 406 river samples analyzed for ichthyoplankton, 129 samples were also analyzed for macroinvertebrates.

Flow rates in the river for April-September 1988 (Figure 2-3) were recorded at the Wilmington spillway (U.S. Geological Survey), which is located approximately 5.6 kilometers downstream of the intake. As in the past, it was assumed that there was no difference in flow rates between the Wilmington spillway and the sampling area (Bergman et. al. 1980). Flow rates in the river for each sampling date are presented in Table 2-2.

2.1.1.2 Horse Creek

Ichthyoplankton samples were collected each Tuesday from 19 April to 13 September, in Horse Creek approximately 1.2 km upstream of its mouth in an area known as the "big riffle" (Sule and Skelley 1985) (Figure 2-1). Four replicate samples were collected consecutively at one location (H1) during the day and again during the night during each 24-hour period. This yielded a total of 8 samples each sampling period. A conical net attached to a square frame (as described in Section 2.1.1.1) was secured to poles driven into the substrate. The net was raised and lowered into the water by hand. Nets remained in the water from 7 to 35 minutes depending on current velocity and depth. Times were adjusted to yield sample volumes of about $40m^3$. On most sampling dates, a portion of the net was exposed so the period of time the net was left in place was increased to compensate for the amount of net exposed.

Of the 136 samples analyzed for ichthyoplankton, 18 samples were also analyzed for macroinvertebrates. All samples were preserved in the field with 10 percent formalin containing rose bengal.

Stream discharge of Horse Creek (Table 2-2) was calculated in accordance with USGS procedures (USGS 1969) once during each 24-hour sampling period. To calculate discharge, a line marked in 1.25 and 2.5 ft. intervals, was stretched across the stream. Depths and velocities were measured at every 2.5 ft. interval along the line. When appropriate, additional measurements were taken at 1.25 intervals in order to keep the flow in any one segment (vertical) to <10 percent of the total flow. A permanent marker was established on the right bank of the creek and distance offshore was measured from this fixed point to the waters edge on each date of discharge measurements. Velocity measurements were taken with a calibrated Marsh-McBirney current meter. Measurements were made at 0.6 depth below the surface because water depth did not exceed 2.5 ft during the study.

TABLE 2-1 DEPTH AT EACH SAMPLING LOCATION DURING ICTHYOPLANKTON COLLECTIONS FROM THE KANKAKEE RIVER, 1988

Date	Location			
	K1	K2	K3	K4
19APR	5.5[a]	6.0	5.5	NC[b]
26APR	NC	NC	NC	NC
3MAY	4.0	6.0	6.2	2.7
10MAY	4.7	4.2	6.3	2.3
17MAY	4.4	4.8	3.8	2.0
24MAY	4.3	5.6	5.1	1.7
31MAY	3.8	5.3	3.8	1.4
7JUN	3.7	4.5	3.2	1.5
14JUN	3.3	5.7	4.2	1.3
21JUN	3.1	6.5	5.4	1.3
28JUN	2.6	3.9	5.2	1.1
5JUL	2.4	3.8	5.1	1.1
12JUL	2.6	3.5	NC	0.9
19JUL	2.8	3.9	5.3	NC
26JUL	2.5	6.3	5.6	0.9
2AUG	2.8	6.1	5.1	1.1
9AUG	2.8	5.6	5.2	0.9
16AUG	3.1	3.5	5.7	1.2
23AUG	3.1	3.8	5.8	1.3
30AUG	2.9	5.7	5.4	1.1
1SEP	3.4	5.4	5.4	1.2
13SEP	3.6	5.6	6.2	1.5

(a) Depth in feet.
(b) No collection made.

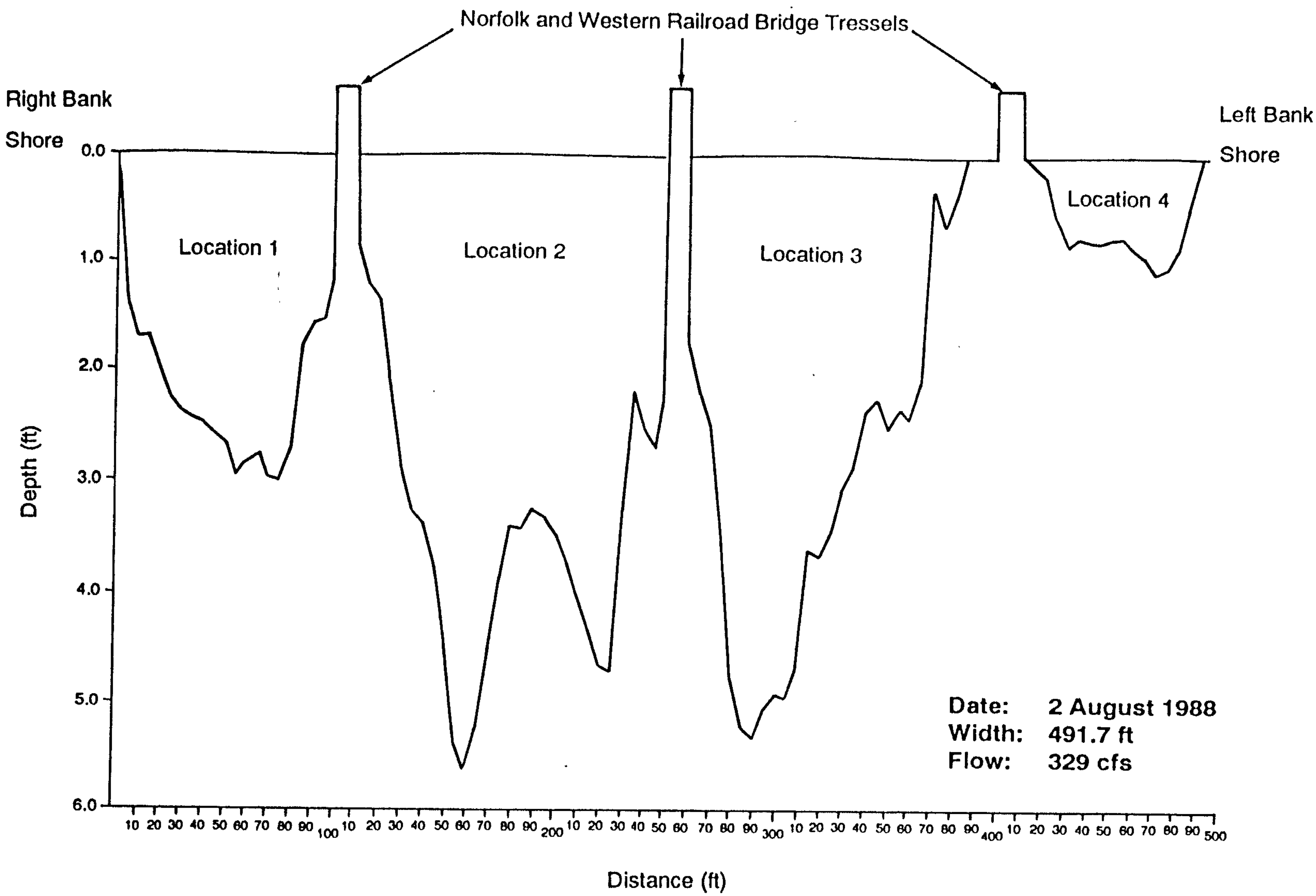


Figure 2-2. Bathymetric cross-section showing width and depth of each sampling location in the Kankakee River, 1988.

Figure 2-3.

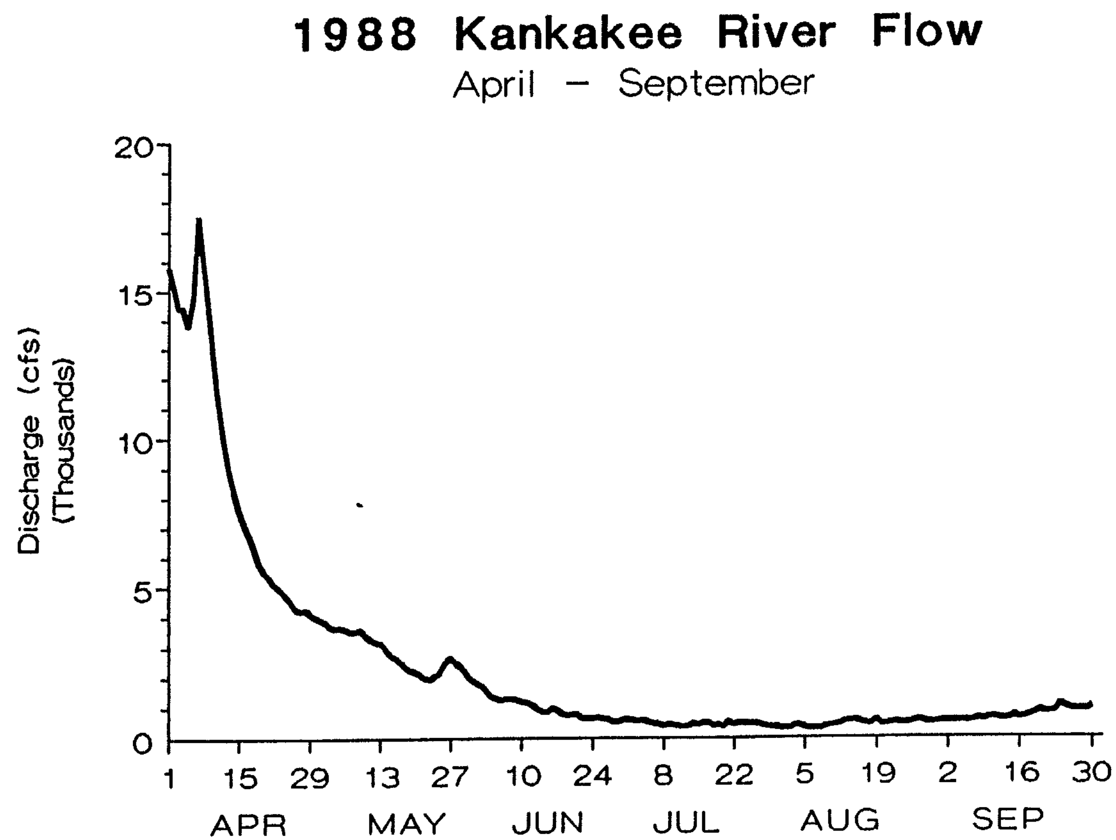

1988 Kankakee River Flow
April – September
Discharge (cfs)
(Thousands)
0
5
10
15
20
1
15
29
13
27
10
24
8
22
5
19
2
16
30
APR
MAY
JUN
JUL
AUG
SEP

TABLE 2-2 SUMMARY OF FLOWS IN HORSE CREEK AND THE KANKAKEE RIVER FOR THOSE DATES WHEN ICHTHYOPLANKTON SAMPLES WERE COLLECTED IN 1988

Date	Horse Creek (cfs)	Horse Creek (m^3/sec)	Kankakee River (cfs)	Kankakee River (m^3/sec)
19 April	51.8	1.47	5,800	164.26
26 April	48.6	1.38	4,300	121.78
3 May	38.6	1.09	3,690	104.50
10 May	39.6	1.12	3,410	96.57
17 May	29.1	0.82	2,510	71.08
24 May	33.2	0.94	2,090	59.19
31 May	15.9	0.45	1,970	55.79
7 June	10.6	0.30	1,320	37.38
14 June	6.1	0.17	889	25.18
21 June	3.5	0.10	785	22.23
28 June	2.2	0.06	532	15.07
5 July	2.5	0.07	535	15.15
12 July	.5	0.01	392	11.10
19 July	1.6	0.04	448	13.00
26 July	2.5	0.07	484	13.71
2 August	.4	0.01	329	9.32
9 August	7.0	0.20	362	10.25
16 August	1.5	0.04	508	14.39
23 August	6.4	0.18	508	14.39
30 August	5.1	0.14	484	13.71
6 September	2.7	0.08	535	15.15
13 September	2.1	0.06	594	16.82

2.1.1.3 Intake

The intake was sampled each Tuesday from 19 April through 13 September 1988. Plankton nets (as described in Section 2.1.1.1) were suspended in the forebay of the intake between the trash racks and the traveling screens. In each of two intake bays at the river screenhouse, two locations within each bay (I1 and I2 in upstream bay and I3 and I4 in downstream bay) and two depths (near surface and near bottom) were sampled once during the day and again during the night during each 24-hour period. The sampling sequence was randomized to the extent possible. Due to low and variable velocities in the intake bays, various sampling schemes were used to collect up to 16 samples on each date. As previously mentioned, the specifications called for sampling four locations at two depths; because of low current velocities, this could be accomplished on only 3 of the 22 sampling dates. On all other dates, replicates were taken in areas where velocity was sufficient to yield a 40 m^3 sample. Filtering times for a 40 m^3 sample ranged from 15 to 50 minutes. On some dates samples of <40 m^3 were kept in order to provide data for that date. No samples were collected during periods when the plant was decoupled (Table 1-1). Of the 264 samples analyzed for ichthyoplankton, 37 samples were also analyzed for macroinvertebrates. All samples were preserved in the field with 10 percent formalin containing rose bengal and returned to the laboratory for processing. Net clogging was not a problem on any date as debris load was very low in the samples collected. Intake pumping rates during each sampling date are presented in Table 2-3.

2.1.1.4 Discharge

On Tuesdays for 13 weeks, beginning April 5th and ending June 28th, day and night replicate, mid-depth, samples were collected in the discharge canal to the Kankakee River. The plankton net (as discussed in Section 2.1.1.1) was suspended in mid-channel, approximately 10 meters downstream of the outfall structure, by a rope and pulley system. During each time period, two replicates were collected consecutively. Filtering times ranged from 8 to 35 minutes to yield a 40 m^3 sample volume. All samples were preserved in the field with a 10% formalin solution containing rose bengal.

All samples were collected at the discharge as scheduled. Of the 52 samples analyzed for ichthyoplankton, 10 were also analyzed for macroinvertebrates. Discharge flow data for each sampling date is presented in Table 2-4.

2.1.1.5 Fish Survival

Intake and Discharge survival studies were conducted three times at each site from early June through early July, with all sampling being at least 6 days apart. The discharge studies were conducted only during the day, whereas the intake studies were conducted only during

TABLE 2-3 REPORTED TOTAL VOLUME PUMPED ON EACH SAMPLING DATE AT THE BRAIDWOOD INTAKE 1988

DATE	MG[a]
19APR	70.56
26APR	60.25
3MAY	65.28
10MAY	56.88
17MAY	69.12
24MAY	66.24
31MAY	69.12
7JUN	69.12
14JUN	72.0
21JUN	69.12
28JUN	69.12
5JUL	55.35
12JUL	OFF[b]
19JUL	39.82
26JUL	OFF
2AUG	OFF
9AUG	OFF
16AUG	41.76
23AUG	21.96
30AUG	69.12
6SEP	69.12
13SEP	64.80

(a) Million Gallons.
(b) Plant decoupled.

TABLE 2-4 REPORTED VOLUME RELEASED ON EACH SAMPLING DATE AT THE BRAIDWOOD DISCHARGE, 1988

Date	MG[(a)]
5APR	20.4
12APR	20.0
19APR	20.3
26APR	20.0
3MAY	20.1
10MAY	19.2
17MAY	19.4
24MAY	19.7
31MAY	19.2
7JUN	20.6
14JUN	21.3
21JUN	20.5
28JUN	8.4

(a) Million Gallons.

the day and twice at night. A No. 0 mesh plankton net with a 1.0 meter opening was used for all collections. The bucket on the cod end of the net was removed to reduce mortality caused by impinging larvae on the bucket's screen. The cod end was secured by tying it very tightly with a piece of string. Eight to fourteen replicate two minute collections were required to filter a minimum of $100m^3$ for each study. A current meter was initially used to locate areas where velocities were $\leq$ 0.5 ft./sec. The net was either positioned at such locations or allowed to move with the current in order to reduce the collection velocity. Collection velocities for each replicate were continuously monitored by determining the number of counts on the attached flowmeter (G.O. Model 2030) during each two minute sampling period. The volume of water sampled and the average collection velocity were also determined with the flowmeter that was suspended in the mouth of the net.

Following collection, the cod end of the net was placed in a 5 gallon bucket containing water, gently untied and rinsed into the bucket. Small volumes of sample were carefully poured into a glass tray for sorting. An illuminated magnifier was used to aid in the location and recovery of captured fish larvae. Samples were immediately sorted on site into three categories: live, dead-transparent, and dead-opaque. Differences in opacity have been observed among dead fish larvae and it has been suggested the opaque larvae probably died prior to collection, whereas transparent larvae were killed by collection or condenser passage (Marcy 1976; King 1978). Sorting was always completed within 20 minutes of collection. Larvae, separated according to the above three categories, were preserved in 10 percent buffered formalin for later identification. Identification procedures for the survival studies were the same as for the entrainment samples (Section 2.1.2.1).

Survival proportions for individual taxa or life stages were calculated as follows:

$$Sp = \frac{\text{Number of Live Larvae}}{\text{Number of Live and Dead-transparent larvae}}$$

The following assumptions are made when using this formula: 1) opaque larvae are dead before passage, and 2) transparent larvae died during passage through the system. Since transparent larvae are assumed to be killed during passage, survival proportion values should be considered minimal values as some mortality may have been caused by collection.

2.1.2 LABORATORY PROCEDURES

2.1.2.1 Ichthyoplankton

All ichthyoplankton samples were hand picked with the aid of an illuminated magnifier. Larvae from these samples were identified using a dissecting scope equipped with polarizing lenses. Ichthyoplankton identifications were made to the lowest practical taxonomic level using current references and taxonomic keys. A positive separation of Hypentelium and Moxostoma could not be made due to overlapping characteristics. Members of these genera were combined and are referred to as Catostomid D based on Hogue et. al. 1976. Cyprinid N were initially identified by EA as striped shiner. Upon conflicting verifications by two experts, Cyprinid N is most likely striped shiner, but more than one species may be involved. Larvae were categorized as yolk-sac (prolarvae), post yolk-sac (postlarvae), and juveniles. These categories are defined by Auer (1982) as follows:

1. Yolk-sac larvae - Phase of development from the moment of hatching to complete absorption of yolk.

2. Post yolk-sac - Phase of development from the complete absorption of yolk to the development of the full complement of adult fin rays and absorption of finfold. (The post yolk-sac phase, as defined here, does not occur for the family Ictaluridae).

3. Juvenile - Phase of development from complete fin ray development and finfold absorption to sexual maturity.

Total lengths of fish larvae and diameters of fish eggs were measured to the nearest 0.1 mm with an ocular micrometer. A maximum of 30 specimens were measured for each life stage of each taxa in each sample.

Subsampling was implemented only on samples collected from Horse Creek the night of 31 May, during peak catostomid drift. Subsampling of these four samples consisted of sorting out all non-catostomids and identifying them individually. Thirty specimens of the remaining group (catostomids) were then selected at random to determine if all the specimens all were from the same taxon. When it was determined all the catostomids present were from the same taxon, 100 of them were weighed and a mean weight determined. The number of specimens remaining in the sample was estimated using this mean weight value.

A reference collection was compiled for each taxa of fish larvae and was verified by Dr. Jay Hatch of the University of Minnesota's James Ford Bell Museum of Natural History.

2.1.2.2 Macroinvertebrates

Of the 858 samples analyzed for ichthyoplankton, 194 were also analyzed for macroinvertebrates. Two hundred samples were originally scheduled to be analyzed in proportion to the number ichthyoplankton samples collected from 19 April through 29

August. The selection process was stratified so that each date and time period was represented (e.g., of 120 samples from the Kankakee River to be analyzed, 60 samples would be taken from both the day and night collections [=3 samples per day and 3 samples per night for each week of the 20 week sampling period]). However, due to missed samples caused by low flow conditions, a representative cross-section of additional samples from September and other dates was assembled in order to obtain as close to 200 samples as possible. The specific location, depth, or replicate analyzed for each date and time period was chosen at random. The breakdown of the 194 samples was as follows:

	Day	Night	Total
Kankakee River	66	64	130
Intake	18	18	36
Horse Creek	8	10	18
Discharge	5	5	10

Macroinvertebrates were defined as those held by a U.S. Standard No. 30 mesh sieve. Prior to analysis, each sample was rinsed on a No. 30 mesh sieve to remove preservatives. The sample material was then sorted, a small portion at a time, under a dissection microscope at 10X magnification. All organisms, except oligochaetes and chironomids were identified and enumerated during this initial sorting procedure. Oligachaetes and chironomids were placed on glass slides in a non-resinous mounting media for examination under a compound binocular microscope at 40-1000X magnifications. All organisms were identified using state-of-the-art taxonomic keys. A reference collection of each taxa identified was compiled for subsequent verification.

2.1.3 DYE STUDY

Under low flows (<2000 cfs), a riffle area between the mouth of Horse Creek and the Braidwood intake becomes exposed. At flows <1300 cfs, the riffle becomes completely exposed and forms a peninsula jutting out into the river. It was hypothesized that under low flows the exposed riffle might direct water coming out of Horse Creek towards the north (opposite) shore of the river, away from the influence of the Braidwood intake. To determine the path taken by water from Horse Creek when the riffle is exposed, dye studies were conducted under low flow conditions. These low flow studies were done when the plant was pumping and again when it was not pumping.

During the two surveys, Rhodamine dye was added to Horse Creek about 50 m upstream of its mouth. The course of the dye plume was based entirely on visual observations. If necessary, a second aliquot of dye was added near the mouth of Horse Creek to reinforce the intensity of the color. The movement of the plume was tracked by walking along the edge of the river and along the riffle. Once the leading edge of the plume passed the downstream end of the riffle, observations were made from the top of the intake structure.

2.2 IMPINGEMENT

2.2.1 FIELD AND LABORATORY PROCEDURES

Impingement monitoring at the Braidwood Station began on 11 October 1988 and ended on 4 October 1989. Twenty-four hour samples were typically collected three times per week on consecutive days. The sample periods were from approximately 9:00 a.m. Monday to 9:00 a.m. Tuesday; 9:00 a.m. Tuesday to 9:00 a.m. Wednesday; and 9:00 a.m. Wednesday to 9:00 a.m. Thursday. Monday's, Tuesday's, and Wednesday's collections represented the three weekly 24-hour impingement collections. A total of 132 out of a maximum of 156 collections were made during the one-year study. No samples were collected during: 1) legal holidays; 2) periods in which the cooling pond was full and pumping did not occur; or 3) periods when there were mechanical problems at the intake.

Immediately before each sampling period, the traveling screens were manually rotated by station personnel to remove debris and a clean trash basket set into place. At the end of each 24-hour period, the traveling screens, if not already operating, were manually operated to remove all impinged fish. An EA staff member was present when the trash basket was emptied at the end of each sampling period. Fish obviously dead longer than 24 hours were removed from the sample and recorded separately. All fish were identified, counted, weighed, measured, examined for marks or tags and this data was recorded. Minnows were measured and batch weighed. When necessary, due to large numbers of fish, the following subsampling technique was utilized. For less than 30 of a single species in a collection period, each individual was weighed and measured. If over 30 individuals of a species were collected, all fish were counted, and a total weight taken. A minimum of 30 individuals were selected based on an interval calculated from the total number captured divided by 30. For example, if 500 individuals of a species were collected, then every 17th fish was weighed and measured. For an interval between 30 and 60 fish, data was taken such that 30 individuals were weighed and measured. Except for gizzard shad, fish usually were returned to EA's laboratory for processing.

A voucher collection consisting of each species of impinged fish (juvenile and adult, when available) was compiled and will be maintained for a period of five years unless Commonwealth Edison provides notice that the collection can be terminated at an earlier date. The reference collection was verified by Dr. David Etnier, University of Tennessee. All pallid shiners (chubs) collected have been verified by either Dr. Etnier or Dr. Larry Page, Illinois Natural History Survey.

2.2.2 PHYSICAL/CHEMICAL MEASUREMENTS

At the time of sampling, temperature and dissolved oxygen (DO) were measured at one intake bay. A Whitney Model T-10C thermistor was used for temperature measurements and a YSI Model 54A DO meter or Winkler titration was used to measure DO. When the DO meter was used, it was calibrated against a Winkler titration before each use. Temperature (C) and DO (ppm) were measured at top, middle, and bottom depths on all dates.

Velocity profiles were measured during two pump operation during a high and a low flow regime on the Kankakee River. These measurements were made using a Marsh-McBirney Model 201 Current Meter at four locations across each screen bay. The measurements were made at the surface and at every meter in the water column.

Plant operating data (e.g. pumping rates and number of pumps operating) was compiled for the entire study period by CeCo personnel and is included here as Appendix A.

2.2.3 DATA ANALYSIS

The fish collected were expressed as numbers per species per date, and weekly and annual impingement estimates were made for the total catch, and the catches of gizzard shad, smallmouth bass, rock bass, and pallid shiner. Estimates of the total number of fish impinged at the Braidwood Station were calculated by week and for the entire one-year study period based on the assumption that the number of fish impinged on non-sampling dates in a week was equal to the average number impinged on the dates that were sampled that week. Therefore, weekly estimates were calculated using the following formula:

$$\text{Estimated number impinged per week} = \frac{\text{Total number collected per week}}{\text{Sampling hours per week}} \times 168 \text{ hours}$$

The annual estimate was the sum of the weekly estimates.

2.3 PROJECT STAFF

Technical staff who participated in this study are listed in Table 2-5 along with their responsibilities.

TABLE 2-5 EA STAFF AND CONSULTANTS WHO PARTICIPATED IN THE 1988-89 BRAIDWOOD 316(b) STUDY

EA PRINICPAL PROJECT STAFF

Greg Seegert -	Project Manager; Report Preparation; Data Analysis; Fish Identification and Verification; Client Consultation; Staff Supervision.
Joe Vondruska -	Field Crew Leader; Larval Fish Identification; Quality Assurance; Report Preparation; Staff Training; Data Managment.
Ken Cummings -	Principal Field and Laboratory Technician for Impingement and Entrainment Field Collections and Laboratory Processing; Field, Laboratory, and Data Preparation; Staff Training.
Ron Bockelman -	Data Processing and Data Programming Manager.

EA FIELD AND LABORATORY STAFF

Richard Bistry -	Impingement Field Technician
Tom Serafini -	Impingement and Entrainment Field Technician
Lowel LaMarr -	Entrainment Field Technician
Paul Jaderholm -	Entrainment Field Technician and Laboratory Entrainment Processing
Karin Cosner -	Laboratory Entrainment Processing
Tracy Layfield -	Macroinvertebrate Identification
Joe Vondruska -	Larval Fish Identification
Greg Seegert -	Adult Fish Identification
Ken Cummings -	Adult and Larval Fish Sorting

Taxonomic Consultants

Dr. Jay Hatch -	Larval Fish
Dr. Dave Etnier -	Impinged Fish
Mr. Dean Geers -	Macroinvertebrates
Mr. Randy Lewis -	Macroinvertebrates
Mr. Tom Simon -	Larval Fish

3. RESULTS

3.1 ENTRAINMENT

3.1.1 ICHTHYOPLANKTON DRIFT

3.1.1.1 Kankakee River

Weekly ichthyoplankton collections from 19 April through 13 September 1988 from the Kankakee River yielded 21 taxa representing 6 families (Table 3-1). A total of 2,590 larvae and 41 eggs were sorted from the 406 samples collected during the 22-week study. Due to low flow conditions that prevailed during most of the 1988 study period, only 58 percent of the scheduled samples could be collected.

Fish eggs collected during 1988 ranged from 1.3 to 2.0 mm in diameter. Most eggs appeared to be viable and ranged in development from the early cleavage stages to early embryo stages (Long and Ballard 1976). Eggs were present in the drift on only 5 of 19 sampling dates, with 80 percent being collected on 19 July:

Date	Number	Percent	Density (No./10m^3)	Diameter Range (mm)
24 MAY	1	2.4	<0.01	1.8
31 MAY	1	2.4	0.01	1.3
7 JUN	2	4.9	0.01	1.9-2.0
21 JUN	4	9.8	0.03	1.3-1.5
19 JUL	33	80.5	0.56	1.5-1.8

The density of eggs was highest on 19 July (0.64 eggs per 10m^3). All eggs collected in the river were demersal, lacked oil globules, and had very small perivitelline spaces. Based on these characteristics and the size of the eggs, all eggs were probably from cyprinids.

Catostomid D (20.8 percent), carp (18.0 percent), Ictiobinae (11.6 percent), Notropis sp. (11.5 percent), and unidentified cyprinids accounted for 73.0 percent of the total number of larvae collected in the Kankakee River (Table 3-1). Other taxa which composed one percent or more of the total catch included Percina sp. (6.7 percent), Lepomis sp. (5.8 percent), Etheostoma sp. (3.0 percent), fathead minnow (2.3 percent), rock bass (1.6 percent), rainbow/banded darter (1.4 percent), and channel catfish (1.0 percent). Unidentified damaged fish larvae accounted for the remaining 5.3 percent (Table 3-1).

TABLE 3-1 TOTAL NUMBER AND PERCENT OF LARVAE COLLECTED IN THE KANKAKEE RIVER, 1988

Species	No.	%
Gizzard shad	1	0.04
Common carp	467	18.03
Hornyhead chub	11	0.42
Golden shiner	23	0.89
Rosyface shiner	2	0.08
Spotfin shiner	1	0.04
Unid *Notropis*	299	11.54
Fathead minnow	60	2.32
Cyprinid N	1	0.04
Unid cyprinid	287	11.08
Unid *Moxostoma*	2	0.08
Catostomid D	538	20.77
Unid Ictiobinae	301	11.62
Unid catostomid	4	0.15
Channel catfish	26	1.00
Stonecat	18	0.69
Rock bass	41	1.58
Unid *Lepomis*	149	5.75
Smallmouth bass	8	0.31
Unid *Pomoxis*	4	0.15
Unid centrarchid	1	0.04
Rainbow darter	10	0.39
Johnny darter	1	0.04
Rainbow/banded darter	35	1.35
Unid *Etheostoma*	78	3.01
Logperch	1	0.04
Unid *Percina*	173	6.68
Unid percid	14	0.54
Unidentified	34	1.31
All species	2590	100.00

The mean length of all larvae measured from the Kankakee River was 8.3 mm, and ranged from 3.2 to 24.2 mm. Length data for the abundant taxa show that group D catostomids and Ictiobinae were distinctly larger than other taxa:

Taxa	No.	Length (mm) MEAN	MIN	MAX
Carp	451	6.06	4.9	10.5
Notropis sp.	283	5.37	4.2	12.5
Unid Cyprinidae	302	5.69	3.2	10.2
Catostomid D	453	15.56	11.9	22.5
Ictiobinae	285	8.01	5.9	16.0
Lepomis sp.	149	5.69	4.0	13.2
Etheostoma sp.	88	6.60	4.9	13.7
Percina sp.	173	6.77	4.5	24.2

Mean lengths for other common taxa ranged from 5.37 mm (Notropis sp.) to 6.77mm (Percina sp.). The mean length of Catostomid D in the Kankakee River was higher than at the other three sampling areas (i.e. - Discharge, Intake, and Horse Creek).

Larval fish were present on all sampling dates except for the two sampling dates in September and 3 May. The mean density (day and night combined) for the study was 0.85 larvae per $10m^3$, ranging from 0 to 3.87 larvae per $10m^3$. For the period 10 May 28 June, night larval densities were 2 to 10 times higher than day densities (Table 3-2). For the entire study, day densities ranged from 0 to 1.43 larvae per $10m^3$ and averaged 0.37 larvae per $10m^3$; whereas, night densities ranged from 0 to 7.02 larvae per $10m^3$ and averaged 1.27 larvae per $10m^3$ (Figure 3-1).

Mean larval densities (day and night combined) were highest (2.32 to 3.87 larvae per $10m^3$) from 24 May through 7 June. This was the same period that larval densities were also highest at the other three sampling sites (i.e. Horse Creek, Discharge and Intake). Before and after this period, densities in the river ranged from 0 to 1.30 larvae per $10m^3$. The peak on 31 May (3.87 larvae per $10m^3$) was dominated by group D catostomids (probably redhorses) (Figure 3-1). Two secondary peaks, on 21 June and 26 July, were dominated by cyprinids (Appendix B). The temporal occurrence of the five most abundant taxa can be summarized as follows:

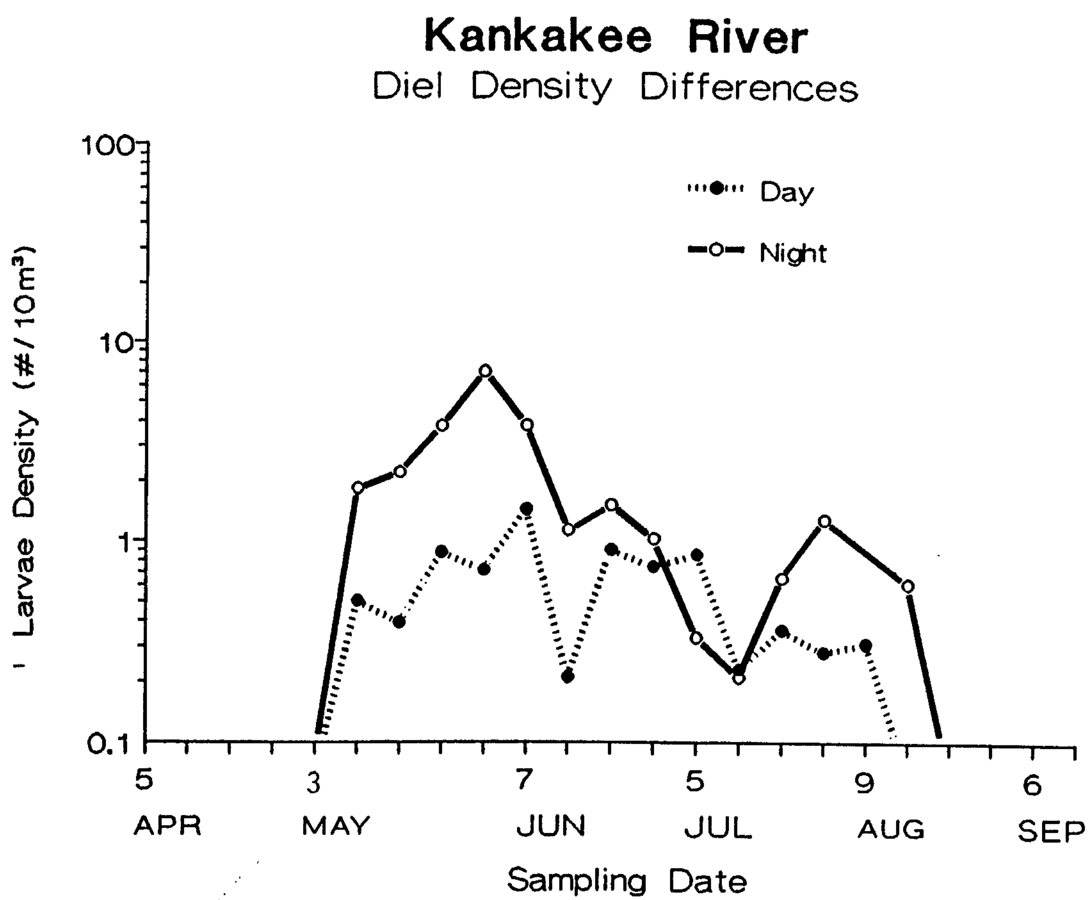
Cyprinidae (except carp)	10 May - 30 August
Catostomidae (except Ictiobinae)	17 May - 7 June
Carp	10 May - 30 August
Ictiobinae sp.	10 May - 7 June
Percina sp.	26 April - 28 June

TABLE 3-2 DIEL DIFFERENCES IN LARVAL FISH DENSITIES DURING ICHTHYOPLANKTON COLLECTIONS IN THE KANKAKEE RIVER, 1988

Date	Day (#/10m^3)	Night (#/10m^3)
19 APR	0.01	0.00
26 APR	0.02	0.02
03 MAY	0.00	0.00
10 MAY	0.50	1.84
17 MAY	0.39	2.21
24 MAY	0.87	3.76
31 MAY	0.71	7.02
07 JUN	1.43	3.78
14 JUN	0.21	1.13
21 JUN	0.90	1.51
28 JUN	0.74	1.02
05 JUL	0.85	0.33
12 JUL	0.23	0.21
19 JUL	0.36	0.65
26 JUL	0.28	1.28
02 AUG	*	*
09 AUG	0.31	*
16 AUG	0.03	0.61
23 AUG	0.02	0.00
30 AUG	0.00	0.06
06 SEP	0.00	0.00
13 SEP	0.00	0.00
MEAN	0.38	1.27

* No samples collected due to low flows.

Figure 3-1.



Kankakee River
Diel Density Differences
Day
Night
Larvae Density (#/10m³)
100
10
1
0.1
5
APR
3
MAY
7
JUN
5
JUL
9
AUG
6
SEP
Sampling Date

The long period during which Cyprinidae (minnows excluding carp) was in the drift was undoubtedly the result of this group being comprised of several species. The Illinois Natural History Survey (INHS) has collected 22 species of minnows (excluding carp and goldfish) in the vicinity of the study area from 1977 through 1988 (Larimore and Peterson 1989). Some of these species such as hornyhead chub and striped shiner may begin spawning as early as late April, while bullhead minnow and spotfin shiners are mid to late summer spawners (Smith 1979).

3.1.1.2 Horse Creek

Weekly ichthyoplankton collections from 19 April through 13 September 1988 from Horse Creek yielded 24 taxa representing 7 families (Table 3-3). A total of 7,087 larvae and 89 eggs were sorted from the 136 samples collected during the 22-week study. Due to insignificant flow rates, samples were not collected on 12 and 19 July; 2 and 16 August; and 13 September; therefore, only 77 percent of the scheduled samples could be collected during the study.

Fish eggs collected during 1988 ranged from 1.0 to 2.5 mm in diameter. Most eggs appeared to be viable and were typically in the early cleavage stage (Long and Bolland 1976). Eggs were present in the drift on only 5 of 17 collection dates, with 86.5 percent of them being collected on 31 May:

Date	Number	Percent	Density No/10m^3	Diameter Range (mm)
10 MAY	1	1.1	0.02	2.5
24 MAY	1	1.1	0.04	1.3
31 MAY	77	86.5	1.88	1.0-1.7
14 JUN	3	3.4	0.08	1.2-1.3
21 JUN	7	7.9	0.17	1.1-1.3
Total	89			

The density of eggs on 31 May was 1.9/10m^3 compared to less than 0.2/10m^3 on the other dates. All eggs (except on 10 May) ranged in diameter from 1.0 to 1.7 mm, were damaged, and lacked oil globule(s). Prolarvae collected in the 2 weeks following the dates on which the eggs were collected were: cyprinids, Lepomis sp., Catastominae (probably Moxostoma sp.), brook silverside, and Etheostoma sp. By the process of elimination, the eggs collected on 31 May are most likely cyprinid eggs. Lepomis sp., brook silverside, and Etheostoma sp. are eliminated based on the lack of an oil globule; and the group Catastominae is eliminated based on their larger egg size: 2.5-3.5 mm (Snyder 1981).

Fish larvae collected in 1988 from Horse Creek were dominated by two taxa which accounted for nearly 90 percent of the total fish larvae drift: Catostomid D (73.2 percent) and unidentified cyprinids (15.0 percent). Other taxa which composed greater than one percent of the total catch included Etheostoma sp. (2.1 percent), Lepomis sp. (2.1 percent) and rock bass (1.2 percent). The other 21 taxa combined comprised only 6.2 percent of the total catch (Table 3-3).

The mean length of larvae measured in Horse Creek was 10.0 mm, and ranged from 3.0 to 21.0 mm. The mean length of larvae collected in Horse Creek was the highest among the four sites sampled. This was primarily due to the greater abundance of group D catostomids in Horse Creek, as they attain a much greater length than most other taxa before they drift. The mean lengths of Notropis sp., unidentified cyprinidae, Lepomis sp., and Etheostoma sp. were also higher in Horse Creek than at the other three sites (i.e. Discharge, Intake, and the Kankakee River). Length data for selected taxa collected in Horse Creek 1988 are presented below:

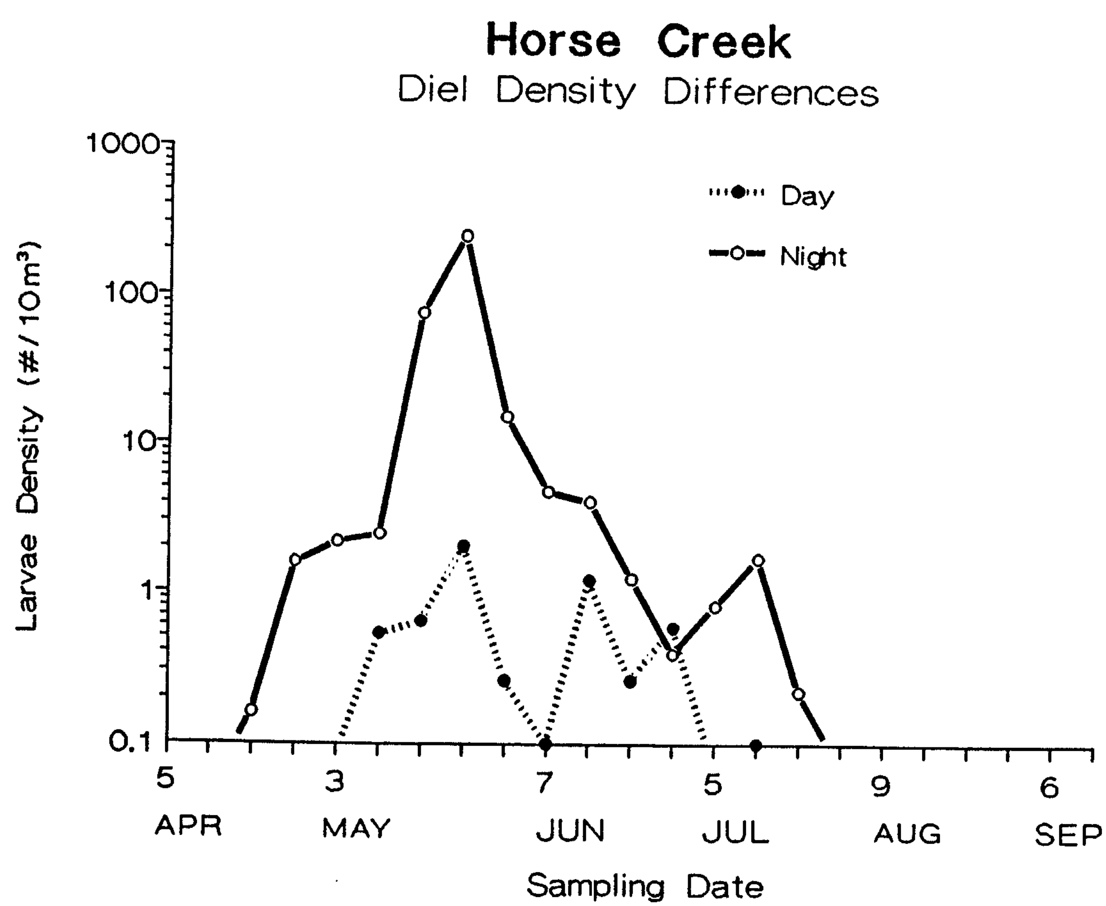
		Length (mm)		
Taxa	No.	MEAN	MIN	MAX
Carp	10	9.24	7.5	10.8
Notropis sp.	46	6.12	4.6	17.5
Unid Cyprinidae	397	7.37	3.0	11.8
Catostomid D	337	14.98	5.0	20.9
Ictiobinae	11	8.67	6.7	13.1
Lepomis sp.	150	6.97	4.6	21.0
Etheostoma sp.	148	7.68	4.7	17.5
Percina sp.	42	6.79	5.4	9.8

Larval fish were present on all sampling dates in Horse Creek. The mean density for the study was 10.76 larvae per $10m^3$, ranging from 0.03 to 124.95 larvae per $10m^3$. Mean larval densities (diel periods combined) were high (7.75-124.95 larvae per $10m^3$) from 24 May through 7 June. Before and after this period, densities typically ranged between 0.05 and 1.50 larvae per $10m^3$. With the exception of 19 April and 5 July, night densities were consistently higher than day densities (Figure 3-2). Night densities ranged from 0 to 247.89 larvae per $10m^3$ and averaged 21.18 larvae per $10m^3$; whereas, day densities ranged from 0 to 2.05 larvae per $10m^3$ and averaged 0.34 larvae per $10m^3$:

TABLE 3-3 TOTAL NUMBER AND PERCENT OF LARVAE COLLECTED IN HORSE CREEK, 1988

Species	No.	%
Gizzard shad	1	0.01
Common carp	10	0.14
Hornyhead chub	29	0.41
Golden shiner	31	0.44
Spotfin shiner	3	0.04
Sand shiner	1	0.01
Unid *Notropis*	49	0.69
Suckermouth minnow	10	0.14
Bluntnose minnow	2	0.03
Fathead minnow	14	0.20
Unid *Pimephales*	1	0.40
Cyprinid N	28	0.40
Unid cyprinid	1066	15.04
Northern hog sucker	2	0.03
Catostomid D	5188	73.20
Unid Ictiobinae	11	0.16
Unid catostomid	16	0.23
Yellow bullhead	3	0.04
Channel catfish	9	0.13
Stonecat	1	0.01
Brook silverside	2	0.03
Rock bass	86	1.21
Unid *Lepomis*	149	2.10
Smallmouth bass	35	0.49
Rainbow darter	10	0.14
Fantail darter	1	0.01
Johnny darter	26	0.37
Rainbow/banded darter	98	1.38
Unid *Etheostoma*	150	2.12
Unid *Percina*	42	0.59
Unid percid	6	0.08
Unidentified	7	0.10
All species	7087	100.00

Figure 3-2.



Horse Creek
Diel Density Differences
Day
Night
Larvae Density (#/10m³)
1000
100
10
1
0.1
5
APR
3
MAY
7
JUN
5
JUL
9
AUG
6
SEP
Sampling Date

	DAY #/10m^3	NIGHT #/10m^3
DATE		
19APR88	0.05	0.00
26APR88	0.00	0.16
03MAY88	0.00	1.60
10MAY88	0.04	2.19
17MAY88	0.53	2.48
24MAY88	0.64	77.09
31MAY88	2.05	247.89
07JUN88	0.26	15.22
14JUN88	0.10	4.79
21JUN88	1.21	4.10
28JUN88	0.26	1.24
05JUL88	0.58	0.39
26JUL88	0.00	0.81
09AUG88	0.10	1.70
23AUG88	0.00	0.22
30AUG88	0.00	0.05
06SEP88	0.00	0.08
Mean	0.34	21.18

The peak on 31 May (103.55 larvae per 10m^3) (Figure 3-2) was dominated by group D catostomids (probably redhorses). Two secondary peaks, on 21 June and 9 August, were comprised almost entirely of cyprinids and Lepomis sp. (Figure 3-2). The temporal occurrence of the five most common taxa can be summarized as follows:

Catostomidae (except Ictiobinae)	10 May - 21 June
Cyprinidae (except carp)	10 May - 6 September
Etheostoma sp. (all taxa)	3 May - 28 June
Lepomis sp.	7 June - 23 August
Rock bass	31 May - 21 June

The peak density of all above-mentioned taxa except Lepomis sp. occurred on 31 May (week 7) (Appendix B). The long periods during which Lepomis sp. (sunfish) and particularly Cyprinidae (minnows) were in the drift was undoubtly the result of each of these taxa being comprised of several species; some of which are early spawners (e.g., hornyhead chub and striped shiner) and others being late spawners (e.g. bullhead minnow and spotfin shiner).

3.1.1.3 Intake

Weekly ichthyoplankton collections from 19 April through 13 September 1988 from the Intake yielded 31 taxa representing 9 families (Table 3-4). A total of 7,197 larvae and 271 eggs were sorted from the 264 samples collected during the 22-week study. The 264 samples analyzed represented 75 percent of the scheduled samples. Samples were missed due to low intake velocities (see Section 2.1.3) and dates when the Intake was decoupled due to low flows in the river (Table 1-1). More larvae, eggs, and taxa were present at the intake than at any other site.

Fish eggs collected at the intake ranged in size from 1.0 to 2.0 mm in diameter. Except for those collected on 26 April and 5 July, all eggs appeared to be viable. Eggs ranged in development from early cleavage stages to well-developed larvae still encased in the chorion (24 May). Eggs were present in collections on 10 of 18 sampling dates, with 62 percent being collected on 24 May:

Date	Number	Percent	Density (No./10m^3)	Diameter Range(mm)
26 APR	1	0.4	0.01	2.0
17 MAY	43	15.9	2.35	1.6 - 2.0
24 MAY	168	62.0	1.59	1.6 - 1.9
31 MAY	32	11.8	0.27	1.1 - 1.9
7 JUN	15	5.5	0.09	1.3 - 1.7
14 JUN	2	0.7	0.01	1.1
21 JUN	6	2.2	0.06	1.1 - 1.5
28 JUN	1	0.4	0.01	1.0
5 JUL	1	0.4	0.01	1.6
19 JUL	2	0.7	0.01	1.1 - 1.2
TOTAL	271			

The largest number of eggs was collected on 24 May, but the density of eggs was highest on 17 May (2.35 eggs per 10m^3). Although at least three distinctly different eggs were collected, one type of egg was most abundant and comprised 89 percent of the total egg catch. This egg ranged in diameter from 1.6 to 2.0mm; it was opaque in early stages of development, lacked an oil globule, and was adhesive. This egg was present in collections from 17 May to 31 May but most were collected on 24 May. Most of these eggs collected on 24 May contained larvae that were fully developed and ready to hatch. Upon removal of a few larval specimens, it was determined that these were carp eggs. The other eggs appeared to belong to a darter sp. (a single egg), and two different types of eggs most likely from the cyprinidae family. Most of the eggs collected at the intake occurred 1-2 weeks before peak egg densities in Horse Creek. Also, given the adhesive nature of the most

TABLE 3-4 TOTAL NUMBER AND PERCENT OF LARVAE COLLECTED AT THE BRAIDWOOD INTAKE

Species	No.	%
Unid gar	2	0.03
Gizzard shad	45	0.63
Common carp	1187	16.49
Hornyhead chub	34	0.47
Golden shiner	138	2.61
Rosyface shiner	2	0.03
Spotfin shiner	5	0.07
Sand shiner	2	0.03
Unid *Notropis*	765	10.63
Suckermouth minnow	23	0.32
Bluntnose minnow	4	0.06
Fathead minnow	130	1.81
Unid *Pimephales*	2	0.03
Cyprinid N	9	0.13
Unid cyprinid	1562	21.70
Unid *Moxostoma*	3	0.04
Catostomid D	908	12.62
Unid Ictiobinae	126	1.75
Unid catostomid	20	0.28
Yellow bullhead	7	0.10
Channel catfish	35	0.49
Stonecat	16	0.22
Blackstripe topminnow	1	0.01
Brook silverside	17	0.24
Rock bass	127	1.76
Unid *Lepomis*	547	7.60
Smallmouth bass	16	0.22
Unid *Pomoxis*	2	0.03
Unid centrarchid	2	0.03
Unid *Ammocrypta*	1	0.01
Rainbow darter	18	0.25
Fantail darter	1	0.01
Johnny darter	6	0.08
Rainbow/banded darter	21	0.29
Unid *Etheostoma*	265	3.68
Unid *Percina*	1001	13.91
Unid *Stizostedion*	2	0.03
Unid percid	46	0.64
Unidentified	49	0.68
All species	7197	100.00

abundant egg collected at the intake and the lack of eggs in the river drift during this period, it is likely that most of the eggs collected at the intake had been spawned in or very near the intake.

Larvae collected in the Intake during 1988 were dominated by unidentified cyprinids (21.7 percent), carp (16.5 percent), Percina sp. (13.9 percent), Catostomid D (12.6 percent) and Notropis sp. (10.6 percent) (Table 3-4). Other common taxa (greater than 1.0 percent) included Lepomis sp. (7.6 percent), Etheostoma sp. (3.7 percent), golden shiner (2.6 percent), rock bass (1.8 percent), and Ictiobinae sp. (1.8 percent). A single 15.5 mm specimen of Ammocrypta sp. was collected on 5 July. This is a new record for the Kankakee River in Illinois (Smith 1979; Dr. Larry Page - personal communication) and is on the Illinois list of endangered species. This specimen was verified by Dr. David Etnier of the University of Tennessee and Mr. Thomas Simon of the Large Rivers Larval Research Station and has subsequently been deposited at the Illinois Natural History Museum. Due to the specimen's small size and lack of literature on larval Ammocrypta it could not be identified to species. Other species collected only at the Intake included Stizostedeon sp. (walleye or sauger), and Lepisosteus sp. (unidentified gar), and blackstripe topminnow.

The mean length of larvae measured at the Intake was 7.5 mm, and ranged from 3.4 to 19.9 mm. Length data indicate that Catostomid D and Ictiobinae specimens were larger than other taxa commonly collected at the Intake:

		Length (mm)		
Taxa	No.	MEAN	MIN	MAX
Carp	768	6.79	4.4	12.4
Notropis sp.	776	5.84	4.2	12.4
Unid Cyprinidae	1255	6.33	3.4	12.1
Catostomid D	559	14.94	9.8	19.9
Ictiobinae	125	9.34	6.3	16.7
Lepomis sp.	542	5.89	3.9	15.7
Etheostoma sp.	267	6.15	4.7	15.5
Percina sp.	965	6.99	4.8	16.5

Mean lengths for the other common taxa ranged from 5.84 mm (Notropis sp.) to 6.99 mm (Percina sp.). The mean lengths of Ictiobinae and Percina sp. were larger at the Intake than in Horse Creek or in the Kankakee River.

The mean of all measured larvae at the Intake was distinctly smaller (7.55 mm) than for Horse Creek (10.01 mm) and slightly smaller than in the Kankakee River (8.34 mm). Mean lengths were more similar between the Intake and the Kankakee River than between the Intake and Horse Creek, suggesting that the composition of the Intake was influenced more by larvae drifting in the Kankakee River than by those produced in Horse Creek.

Of the 31 taxa collected at the Intake, 24 were common between the Intake and Horse Creek; and 21 were common between the Intake and the Kankakee River. The species composition at the Intake appears to be a combination of Horse Creek and Kankakee River taxa. In addition to the four taxa that were unique to the Intake, several taxa were present at only two of the three locations:

Taxa	Intake	Kankakee R.	Horse Creek
Rosyface shiner	X	X	
Spotfin shiner	X		X
Sand shiner	X		X
Suckermouth minnow	X		X
Pimphales sp.	X		X
Bluntnose minnow	X		X
Yellow bullhead	X		X
Brook silverside	X		X
Pomoxis sp.	X		X
Fantail darter	X		X

For some of the less abundant taxa, it appears that species composition at the intake is a combination of taxa from both Horse Creek and the Kankakee River. However, a comparison of common taxa shows that the number and percent abundance of these taxa are more similar between the Intake and the Kankakee River than between the Intake and Horse Creek:

	Kankakee R.		Intake		Horse Creek	
Taxa	No.	%	No.	%	No.	%
Catostomid D	538	20.8	908	12.6	5188	73.2
Cyprinidae	287	11.1	1562	21.7	1066	15.0
Carp	466	18.0	1187	16.5	10	0.1
Notropis sp.	299	11.5	765	10.6	49	0.7
Ictiobinae sp.	301	11.6	126	1.8	11	0.2
Percina sp.	173	6.7	1001	13.9	42	0.6
Etheostoma sp.	78	3.0	265	3.7	150	2.1
Lepomis sp.	148	5.7	547	7.6	149	2.1
Rock bass	41	1.6	127	1.8	86	1.2

Catostomids dominated the Horse Creek drift and were the second most abundant taxa collected in the Kankakee River and the third most abundant taxa at the Intake. Conversely, Cyprinidae dominated the Kankakee River and Intake drift while catostomids ranked second or third. Carp was the second most abundant taxa at the intake; it was also common in the river, but rare in Horse Creek. The percent composition of these three major taxa and of Lepomis sp., and Percina sp. are more similar between the Kankakee River and the Intake than between the Intake and Horse Creek. The percent composition of Etheostoma sp. and rock bass were similar among all three sites, whereas, Ictiobinae larvae were noticeably more prevalent in the river than at either of the other two sites. The greater raw numbers of cyprinids, carp, Percina sp. and Lepomis sp. at the Intake may suggest that these taxa spawn in the vicinity of the intake.

Larval fish were present on all sampling dates at the Intake. The mean density (diel periods combined) for the study was 3.66 larvae per $10m^3$, ranging from 0.01 to 16.50 larvae per $10m^3$. On all sampling dates, night densities were higher than day densities (Figure 3-3). Night densities ranged from 0.02 to 36.10 larvae per $10m^3$ and averaged 6.52 larvae per $10m^3$. Day densities ranged from 0 to 2.61 larvae per $10m^3$ and averaged 0.79 larvae per $10m^3$ (Table 3-5). Peak mean density (diel periods combined) for the Intake study occurred on 24 May (16.50 larvae/$10m^3$). This peak was attributable to carp (7.6 larvae/$10m^3$), cyprinids (4.7 larvae/$10m^3$), Percina sp. (2.8 larvae/$10m^3$), and catostomids (2.2 larvae/$10m^3$) (Appendix B). Smaller peaks occurred on 19 July and 23 August. The peak on 19 July was composed of Lepomis sp. and unidentified cyprinids and the peak on 23 August was comprised exclusively of cyprinids.

The temporal occurrence of the five most abundant taxa can be summarized as follows:

Cyprinidae (except carp)	10 May - 6 September
Carp	17 May - 30 August
Percina sp.	19 April - 21 June
Catostomidae (except Ictiobinae)	10 May - 7 June
Lepomis sp.	31 May - 30 August

3.1.1.4 Discharge

Weekly ichthyoplankton collections from 19 April through 28 June from the discharge canal yielded 15 taxa representing 9 families (Table 3-6). A total of 631 larvae and 182 eggs were found in the 52 samples collected during the 13-week study.

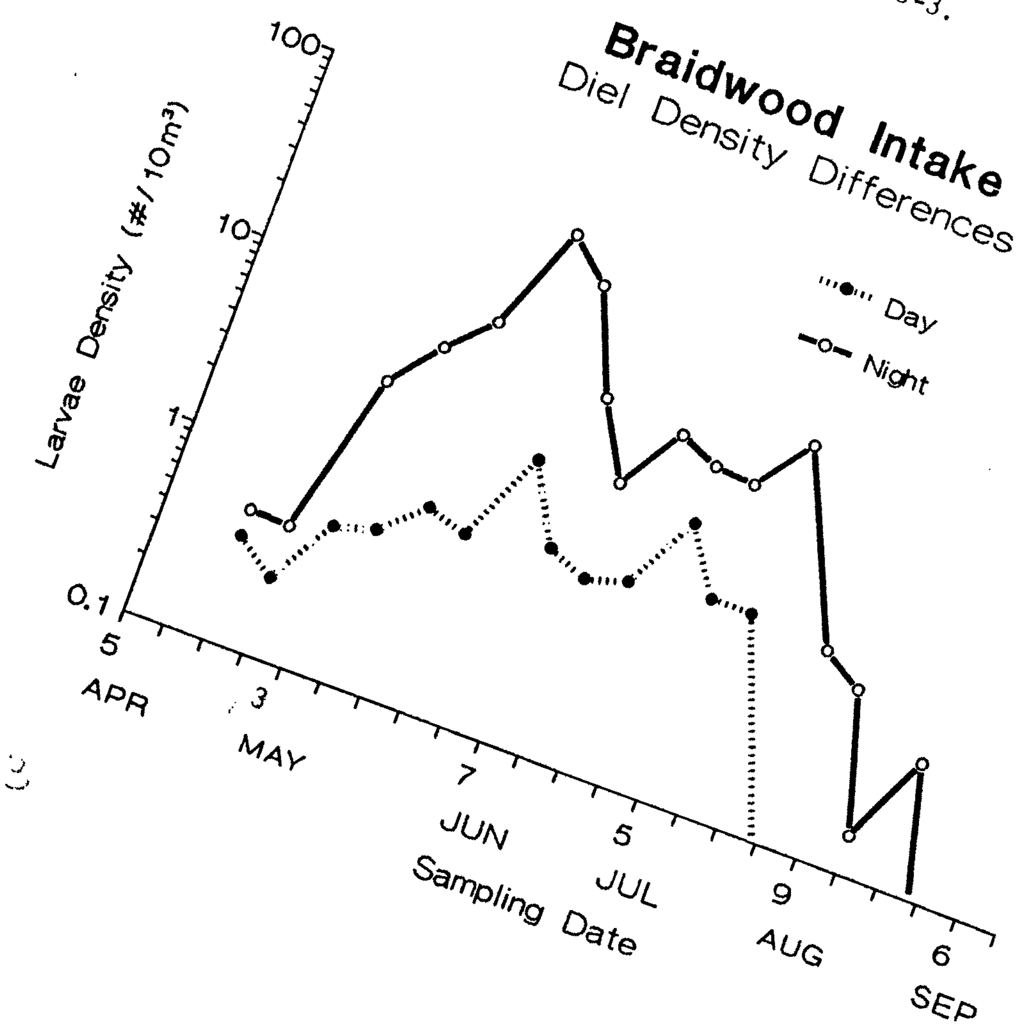
Fish eggs collected during 1988 ranged from 0.8 to 2.3 mm in diameter. All eggs appeared to be viable and were in the early cleavage stages of development (Long and Ballard 1976).

TABLE 3-5 DIEL DIFFERENCES IN LARVAL FISH DENSITIES DURING ICHTHYOPLANKTON COLLECTIONS AT THE BRAIDWOOD INTAKE, 1988

Date	Day (#/10m^3)	Night (#/10m^3)
19 APR	0.35	0.48
26 APR	0.25	0.47
03 MAY	0.56	3.35
10 MAY	0.64	6.09
17 MAY	1.01	10.09
24 MAY	0.87	36.10
31 MAY	2.61	23.13
07 JUN	1.06	6.78
14 JUN	0.87	2.84
21 JUN	1.01	6.22
28 JUN	2.49	5.03
05 JUL	1.17	4.80
12 JUL	*	*
19 JUL	1.17	9.54
26 JUL	*	*
09 AUG	*	*
02 AUG	*	*
16 AUG	0.06	1.07
23 AUG	0.04	0.79
30 AUG	0.03	0.16
06 SEP	0.00	0.46
13 SEP	0.00	0.02
MEAN	0.79	6.52

*Pumps not operating because plant decoupled due to low river flows.

Figure 3-3.



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57

TABLE 3-6 TOTAL NUMBER AND PERCENT OF LARVAE COLLECTED AT THE BRAIDWOOD DISCHARGE, 1988

Species	No.	%
Gizzard shad	247	39.14
Common carp	13	2.06
Unid cyprinid	2	0.32
Catostomid D	5	0.79
Unid Ictiobinae	1	0.16
Unid catostomid	3	0.48
Unid ictalurid	2	0.32
Brook silverside	1	0.16
Unid *Morone*	3	0.48
Unid *Lepomis*	13	2.06
Smallmouth bass	1	0.16
White crappie	1	0.16
Unid *Pomoxis*	209	33.12
Unid Centrarchid	1	0.16
Unid *Etheostoma*	2	0.32
Unid *Percina*	11	1.74
Unid percid	7	1.11
Freshwater drum	62	9.83
Unidentified	47	7.45
All species	631	100.00

Eggs were present in the drift on only 5 of the 11 sampling dates, with 74.2 percent being collected on 31 May:

Date	Number	Percent	Density (No./10m^3)	Diameter Range (mm)
17 MAY	14	7.7	0.75	1.4 - 1.6
24 MAY	24	13.2	1.80	0.8 - 2.3
31 MAY	135	74.2	5.60	0.8 - 1.8
07 JUN	6	3.3	0.30	1.2 - 1.3
28 JUN	3	1.6	0.45	1.5

The density of eggs was highest on 31 May (5.6 eggs per 10 m^3). Although four distinctly different eggs were collected; one type of egg was most abundant and comprised 90 percent of the total egg catch. This egg ranged in diameter from 1.3 to 1.6 mm; it was opaque and contained an orangish spot (probably an oil globule). Based on these characteristics and the type and percent of larvae collected; this egg probably is from a centrarchid. The other eggs appeared to belong to gizzard shad, freshwater drum, and the cyprinidae family.

The composition of larvae at the discharge was unlike that from the other locations. Larvae collected in the discharge during 1988 were dominated by gizzard shad (39.1 percent), Pomoxis sp. (33.1 percent), freshwater drum (9.5 percent) and unidentified larvae (7.5 percent) (Table 3-6). The large percent of unidentified larvae (7.45 percent) was due to specimens that were damaged prior to collection. The relative abundance of unidentified larvae at the other three sites ranged from 0.1 to 1.3 percent of the total catch. Other common taxa (greater than 1 percent) included carp (2.1 percent), Lepomis sp. (2.1 percent), Percina sp. (1.7 percent), Catostomidae (1.3 percent), and yellow perch (1.1 percent) (Table 3-6). Freshwater drum and white bass were collected exclusively from the discharge canal. Gizzard shad and Pomoxis sp. were much less abundant at the other three sites comprising 0 to 0.6 percent of the total catch at the other locations.

The mean length of larvae measured in the Discharge was 7.11 mm, and ranged from 3.4 to 20.0 mm. Length data indicate that gizzard shad and carp specimens were larger than other taxa commonly collected at the Discharge:

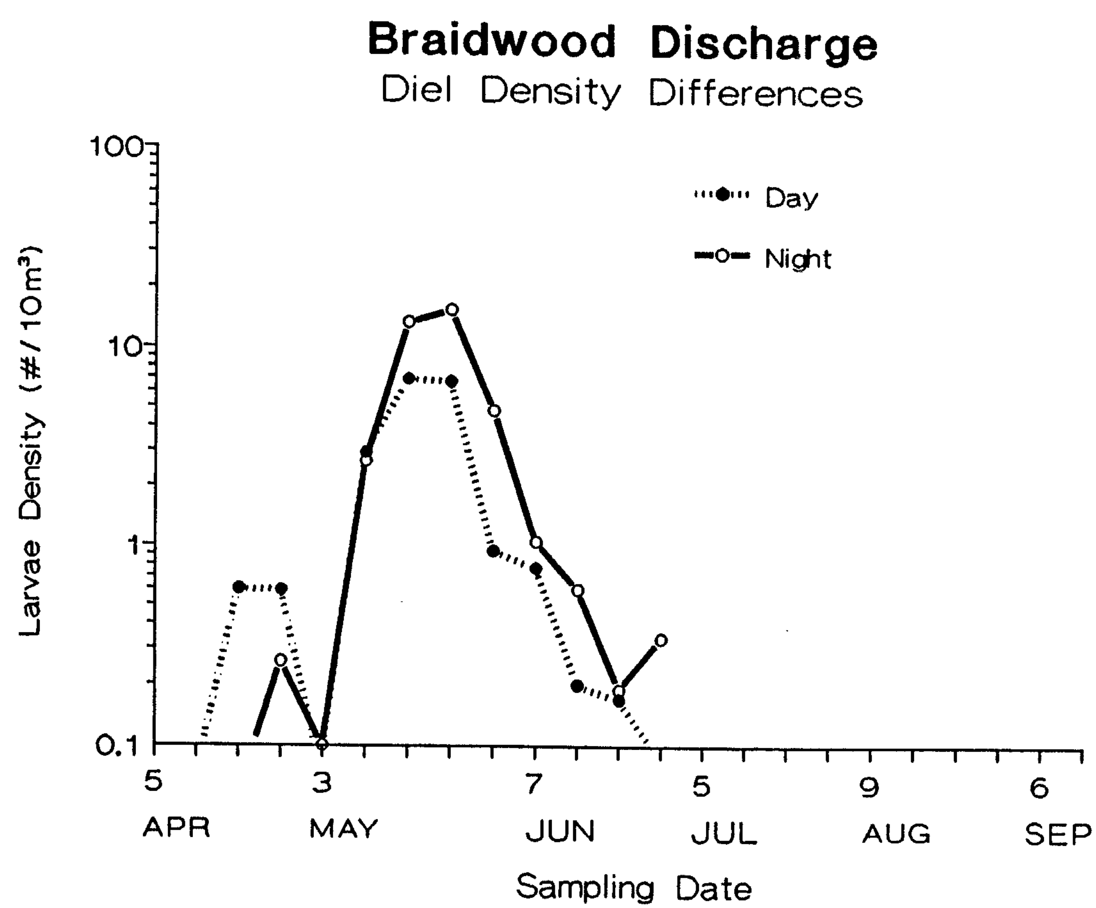
Taxa	No.	Length (mm) MEAN	MIN	MAX
Gizzard shad	232	7.2	3.8	20.0
Pomoxis sp.	206	4.9	4.1	12.8
Freshwater drum	59	4.5	3.8	16.0
Carp	13	6.8	6.2	7.3
Lepomis sp.	13	5.6	5.0	6.2

The mean length for Lepomis sp. specimens at the Discharge was smaller than at the other three sampling sites (i.e. Kankakee River, Horse Creek, and Intake). The mean length of carp larvae was intermediate to values observed at the other sites. Not enough gizzard shad, Pomoxis sp., or freshwater drum larvae were collected at the other sites to make meaningful comparisons.

Larval fish were present on all sampling dates in the discharge. The mean density (diel periods combined) for the study was 2.65 larvae per $10m^3$, ranging from 0.05 to 11.05 larvae per $10m^3$ (Figure 3-4). Mean larval densities were highest (10.15 -11.05 larvae per $10m^3$) on 17 and 24 May; intermediate (2.8 to 2.9 larvae per $10m^3$) on 10 and 31 May; and less than 0.50 larvae per $10m^3$ on all other dates (Appendix B). From 10 May through 31 May when total mean densities ranged from 2.8 to 11.05 larvae per $10m^3$; gizzard shad and Poxomis sp. accounted for greater than 70 percent of the larvae (Figure 3-5). For the first six weeks of the discharge study, day densities were higher than night densities, whereas for the last seven weeks of the study night densities were higher than day densities (Figure 3-4). Day densities ranged from 0 to 6.71 larvae per $10m^3$ and averaged 1.53 larvae per $10m^3$. Night densities ranged from 0 to 15.36 larvae and averaged 2.98 larvae per $10m^3$:

DATE	DAY $\#/10m^3$	NIGHT $\#/10m^3$
05APR88	0.00	0.00
12APR88	0.00	0.00
19APR88	0.60	0.00
26APR88	0.59	0.26
03MAY88	0.00	0.10
10MAY88	2.94	2.67
17MAY88	6.92	13.33
24MAY88	6.71	15.36
31MAY88	0.94	4.80
07JUN88	0.77	1.05
14JUN88	0.20	0.60

Figure 3-4.


Braidwood Discharge
Diel Density Differences
Day
Night
Larvae Density (#/10m³)
100
10
1
0.1
5
APR
3
MAY
7
JUN
5
JUL
9
AUG
6
SEP
Sampling Date

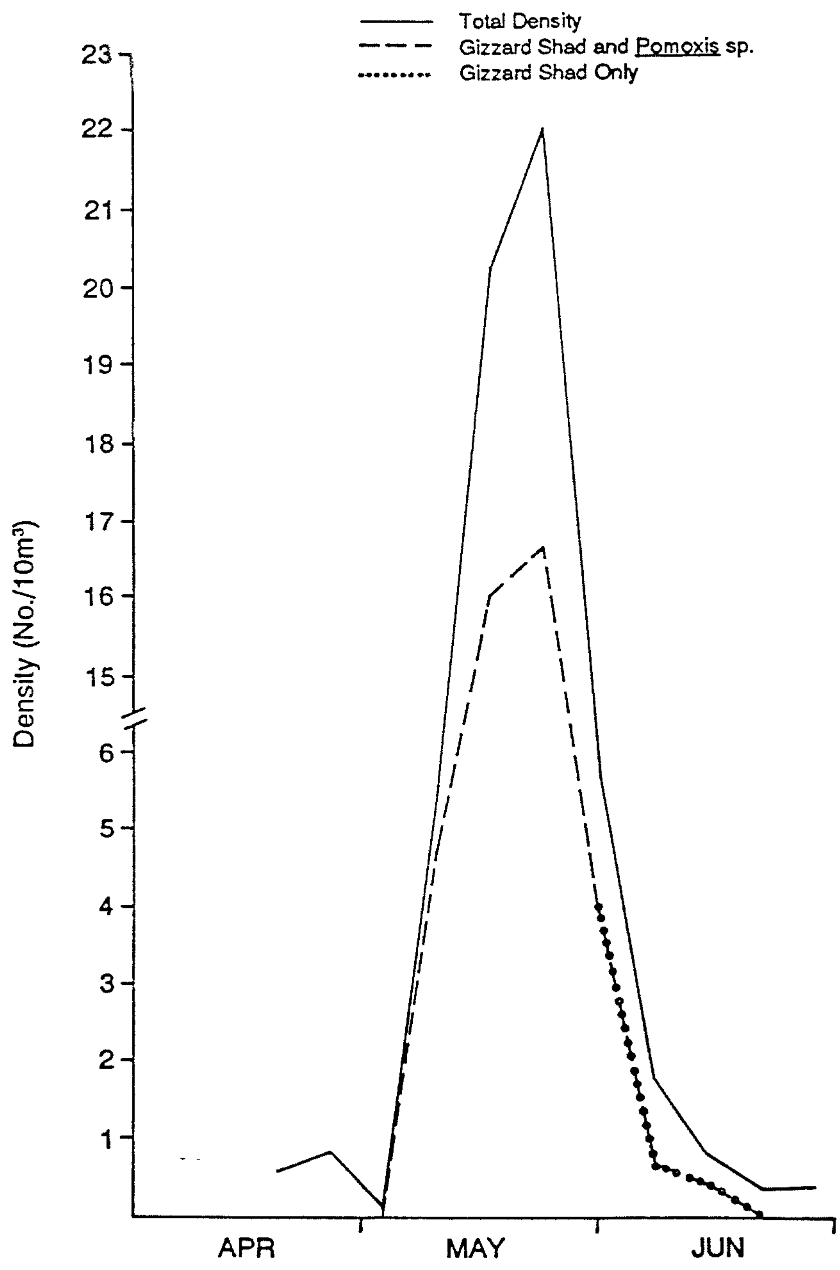


Figure 3-5. Comparison of densities between total catch and the catch of dominant taxa collected at the discharge, 1988.

21JUN88	0.17	0.19
28JUN88	0.08	0.34
MEAN	1.53	2.98

Overall the mean density during the night was about double what it was during the day.

The temporal occurrence of the three most common taxa can be summarized as follows:

Gizzard shad	10 May - 14 June
Pomoxis sp.	10 May - 31 May
Freshwater drum	17 May - 7 June

Gizzard shad, Poxomis sp. and freshwater drum all had peak densities on 24 May.

3.1.1.5 Survival Studies

Intake

The Intake survival studies were conducted in the one acre holding pond to which the river water is pumped before it spills into the cooling pond. These studies occurred during the day on 1 June and during the night on 7 June and 5 July. The net was positioned and/or allowed to move with the current so the velocities were typically maintained at $\leq$ 0.5 ft/sec. Mean calculated collection velocities ranged from 0.39 to 0.55 ft/sec. Total sample volumes collected for each study ranged from 125.1 to 144.1 m^3:

Date	Mean Velocity (ft/sec)	Total Volume (m^3)	Number of Two Minute Replicates
1 June	0.51	144.1	10
7 June	0.55	125.1	8
5 July	0.39	132.3	12

Eight to twelve two minute replicate samples were collected to insure that a minimum of $100m^3$ of water was filtered for each study.

Ichthyoplankton representing 10 taxa were collected during the Intake entrainment survival studies (Table 3-7). Cyprinidae (77.0 percent), Lepomis sp. (6.8 percent), and unidentifiable

TABLE 3-7 TOTAL NUMBER AND SURVIVAL PROPORTIONS OF EACH TAXA AND LIFE STAGE COLLECTED DURING THREE INTAKE ENTRINAMENT SURVIVAL STUDIES AT THE BRAIDWOOD GENERATING STATION, 1988

Taxa	Prolarvae	Postlarvae	Juvenile	Total Number collected	Percent of Total	Survival Proportion
Cyprinidae	11	136	-	147	77.0	0.60
Hornyhead chub	-	1	-	1	0.5	-
Striped shiner	-	1	-	1	0.5	1.00
Catostomidae	-	3	-	3	1.6	-
Yellow bullhead	-	-	2	2	1.0	1.00
Rock bass	-	1	-	1	0.5	1.00
Lepomis sp.	-	10	-	13	6.8	0.78
Etheostoma sp.	-	2	1	3	1.6	1.00
Johnny darter	-	-	2	2	1.0	1.00
Percina sp.	-	3	1	6	3.1	0.75
Unidentified	-	-	-	12	6.3	-
Total	16	157	6	191		
Survival Proportion	0.83	0.62	1.00			0.68

(damaged) larvae (6.3 percent) were the most commonly encountered taxa. Post-larvae was the dominate life stage accounting for 82.2 percent of the total catch. Two-thirds of the larvae collected in the three studies were classified as dead-opaque (Table 3-8) and therefore considered dead before passage. With the exception of post-larval cyprinids, sample sizes for all other taxa and life stages were too small for detailed analyses, but are presented to give some indication of survival potential.

Only 13 larvae representing four taxa were collected during the first study on 1 June (Table 3-8). Eight of the 13 larvae were dead opaque leaving 5 specimens for determining survival proportions. The survival proportions for cyprinidae (based on 2 specimens) and Percina sp. (based on 3 specimens) were 0.50 and 0.67, respectively. The overall survival proportion on 1 June was 0.60 (Table 3-8). Prolarvae and postlarvae were present in each life condition category.

The second study at night on 7 June, yielded 147 larvae representing 9 taxa (Table 3-8). Dead opaque was again the most common life condition encountered, comprising 69 percent of the specimens. Cyprinidae and Lepomis sp. were the two most common taxa and survived entrainment at rates of 0.55 and 0.75, respectively. Striped shiner, rock bass, Etheostoma sp., johnny darter, and Percina sp. exhibited no mortality (survival proportions = 1.00) but they were represented in the study by only five or fewer specimens so estimates for these taxa are tenuous. Postlarvae dominated (73-94 percent) each of the life condition categories:

	Percent Composition		
Life Condition	Prolarvae	Postlarvae	Juveniles
Live	20	73	7
Dead transparent	6	94	-
Dead Opaque	3	88	2

Survival rates for prolarvae, postlarvae, and juveniles on 7 June were 0.86, 0.59, and 1.00, respectively.

The final study was conducted at night on 5 July. Thirty larvae were collected representing three taxa (Table 3-8). Sixty-three percent of the larvae collected were dead before entrainment. Of the remaining 11 larvae; 2 juvenile yellow bullhead, 7 cyprinidae (4 postlarvae and 3 prolarvae), and 1 postlarval Lepomis sp. were collected alive. Survival proportions for the aforementioned taxa were: yellow bullhead - 1.00; cyprinidae - 0.78, and Lepomis sp. - 1.00. This yielded a survival rate of 0.82 for 5 July.

TABLE 3-8 TOTAL NUMBER AND SURVIVAL PROPORTIONS OF EACH TAXA AND LIFE CONDITION COLLECTED DURING ENTRAINMENT SURVIVAL STUDIES ON 1 JUNE, 7 JUNE, AND 5 JULY 1988

Taxa/Date	Life Condition L[a]	DT[b]	DO[c]	Total Number	Survival[d] Proportion
1 June - (Day)					
Cyprinidae	1	1	4	6	0.50
Catostomidae	-	-	2	2	-
Ethestoma sp.	-	-	2	2	-
Percina sp.	2	1	-	3	0.67
Total	3	2	8	13	0.60
7 June - (Night)					
Cyprinidae	17	14	79	110	0.55
Hornyhead chub	-	-	1	1	-
Striped shiner	1	-	-	1	1.00
Catostomidae	-	-	1	1	-
Rock bass	1	-	-	1	1.00
Lepomis sp.	6	2	9	17	0.75
Etheostoma sp.	3	-	1	4	1.00
Johnny darter	1	-	1	2	1.00
Percina sp.	1	-	2	3	1.00
Unidentified	-	-	7	7	-
Total	30	16	101	147	0.65
5 July - (Night)					
Cyrpinidae	7	2	13	22	0.78
Yellow bullhead	7	-	-	2	1.00
Lepomis sp.	1	-	1	2	1.00
Unidentifieid	-	-	5	5	-
Total	9	2	19	30	0.82
Grand Total	43	20	128	191	0.68
Percent	22.5	10.5	67.0		

a) Live
b) Dead-Transparent
c) Dead-Opaque
d) Number of live larvae divided by the number of live plus dead - transparent larvae.

For the three studies combined, 68 percent of larvae survived passage from the river screenhouse to the one acre holding pond (Table 3-8). Survival rates were less than 1.00 for cyprinidae (0.60), Lepomis sp. (0.78), and Percina sp. (0.75). The other taxa did not exhibit entrainment mortality. All specimens of catostomidae and hornyhead chub were collected dead before entrainment so no survival proportion could be estimated for these taxa. Differences in survival rates among life stage was also observed. Post-larvae exhibited the lowest survival rate of 0:62, prolarvae survival was higher at 0.83, whereas no mortality was observed among the few juveniles collected (Table 3-7).

Discharge

The Discharge survival studies were conducted immediately downstream of the outfall structure in the discharge canal. Studies were conducted during daylight on 1, 7, and 21 June 1988. Due to the rocky, uneven substrate of the discharge canal, the net was kept stationary during all collections. Mean collection velocities for the three studies ranged from 0.40 to 0.63 ft/sec:

Total Date	Collection Velocity (ft/sec)	Total Volume (m^3)	Number of two minute Replicates
1 June	0.63	137.1	11
7 June	0.40	109.7	13
21 June	0.40	113.0	14

Total sample volumes for the study ranged from 109.7 to 137.1m^3. Eleven to fourteen replicate two minute samples were collected during each study to insure that a minimum of 100m^3 was filtered. The mean collection velocity on 1 June was slightly higher than the maximum (ie., 0.5 ft/sec) desired. Upon completion of eight replicates on 1 June, it was determined that 7 of the 10 larvae collected were dead opaque. An additional three samples were collected at velocities <0.5 ft/sec; these additional samples produced only 3 dead opaque. Due to the low density of larvae and the dominance of dead opaque larvae, the study was considered valid and sampling was terminated (Dr. Richard Monzingo, personal communication). Total number of larvae collected was insignificant for two of the three studies:

	Total Number
1 June	13
7 June	89
21 June	1

Since only 1 larvae was collected during the 21 June study and 77 percent (10 of 13) of the larvae collected during the 1 June study were dead before entrainment (dead opaque), all dates were combined for analysis. Collectively, the three Discharge studies yielded 103 fish larvae representing 5 taxa. As with the number of taxa collected, life stage representation was also sparse:

	Prolarvae	Postlarvae	Juvenile	Not Determined	Total	Percent of Total
Gizzard shad	-	9	1	-	10	9.7
Carp	1	-	-	-	1	1.0
Lepomis sp.	-	79	-	-	79	76.7
Pomoxis sp.	-	3	1	-	4	3.9
Freshwater drum	-	1	-	-	1	1.0
Unidentified	1	2	-	5	8	7.8
Total	2	93	2	5	103	

Postlarval Lepomis sp. (76.7 percent), gizzard shad (9.7 percent), and unidentifiable (damaged) larvae (7.8 percent) were the dominant taxa collected.

"Live" was the most frequently encountered life condition during the Discharge survival studies due to the good survivability of entrained postlarval Lepomis sp:

Taxa	Live	Dead Transparent	Dead Opaque	Survival Proportion
Gizzard shad	-	3	7	0.00
Carp	-	-	1	-
Lepomis sp.	60	15	4	0.80
Poxomis sp.	1	2	1	0.33
Freshwater drum	-	-	1	-
Unidentifiable	-	-	8	-
Total	61	20	22	0.75

The survival proportion for Lepomis sp. was 0.80. Pomoxis sp. survived at a rate of 0.33, while none of the gizzard survived. All other taxa collected were dead before entrainment. The overall survival rate at the Discharge was (0.75).

3.1.1.6 Statistical Comparisons

One and two way ANOVA's based on log transformed data were used to compare egg and larvae densities at each of the four study areas; Horse Creek, Kankakee River, the Braidwood Intake, and the Braidwood Discharge. As discussed below, diel differences were significant at each study area but other variables (i.e., depth and location) were not significant.

Horse Creek and the Discharge

Because Horse Creek and the Discharge were each sampled at only one location and one depth, the only comparison that could be made was between night and day densities. In Horse Creek, the difference between day and night densities was significant for both larvae and total ichthyoplankton (i.e., eggs plus larvae):

	Mean Density (No./10m^3)			
	Night	Day	Pr*	Pt*
Larvae	21.18	0.34	.0007	.0001
Total IP	21.40	0.38	.0007	.0001

*Pr - Probability based on raw data
Pt - Probability based on log transformed data

The magnitude of the difference between day and night densities was greater in Horse Creek than at any of the other study locations.

In contrast to the situation in Horse Creek, the difference between day and night densities at the Braidwood discharge was the smallest among the four study areas:

	Mean Density (No./10m^3)			
	Day	Night	Pr	Pt
Larvae	1.53	2.98	.007	.026
Total IP	1.64	4.07	.003	.011

Although diel differences were less pronounced at the discharge, the difference was significant both for larvae (P = .026) and for total IP (P=.011).

Intake

Comparisons at the intake were night vs. day, location (upstream vs. downstream bay), and depth (surface vs. bottom). The diel comparisons showed that time of collection was a significant factor affecting larval density:

	Mean Density (No./10m^3)			
	Day	Night	Pr	Pt
Larvae	0.83	6.87	.0001	.0001
Total IP	1.07	6.94	.0001	.0001

Conversely, neither the location of sampling nor the depth of sampling was a significant variable:

	Mean Density (No/10m^3)			
	Surface	Bottom	Pr	Pt
Larvae	3.07	3.68	.459	.379
Total IP	3.23	3.81	.467	.445
	Upstream	Downstream	Pr*	Pt*
Larvae	5.17	3.46	.137	.091
Total IP	5.26	3.63	.145	.084

Kankakee River

The situation in the Kankakee River paralleled that in the intake. That is, time of collection in the river was a significant factor affecting larval density, whereas neither location along the transect nor depth were important variables. The diel comparisons can be summarized as follows:

	Mean Density (No/10m^3)			
	Day	Night	Pr	Pt
Larvae				
(19 Apr. - 28 June, all locations and depths combined)	0.50	2.01	.0001	.0001
(19 Apr. - 13 Sept, Loc K2 Surface)	0.23	1.26	.0006	.0001
(19 Apr. - 13 Sept, Loc K3 Surface)	0.27	1.19	.0026	.0006
Total IP				
(19 Apr. - 28 June, all locations and depths combined)	0.50	2.01	.0001	.0001
(19 Apr. - 13 Sept., Loc K2 Surface)	0.35	1.26	.0051	.0008
(19 Apr. - 13 Sept., Loc K3 Surface)	0.27	1.19	.0026	.0006

During the period 19 April through 28 June samples could be collected at all points and depths along the transect. During this period the density of larvae was four times higher at night than during the day. For the entire study period (i.e., 19 April through 13 September), diel comparisons were restricted to surface samples collected at Locations K2 and K3. At these locations, densities were 4-5 times higher at night than during the day (see above).

Because Location K4 was sampled infrequently due to lack of depth and current speed, statistical comparisons among the locations were largely restricted to Locations K1, K2, and K3, except that surface densities for all locations were compared for the period 19 April through 13 September. The various location comparisons are summarized in Table 3-9.

These comparisons show that larvae and IP were homogeneously distributed across the breadth of the Kankakee River from the beginning of the study through June. Lack of depth and low current speeds prohibited statistical analysis according to location during July and August.

Depth comparisons were also limited because of the shallow water that prevailed throughout the study. Depth was considered at Locations K1-K3 for the period 19 April through 14 June and at Locations K2 and K3 for the period 19 April - 28 June and 16 and 23 August, respectively. These comparisons can be summarized as follows:

	Mean Density (No/10m^3)				
		Surface	Bottom	Pr*	Pt*
19 April through 14 June;	Larvae	1.21	1.32	.647	.167
Locations K1-K3	Total IP	1.21	1.32	.656	.175
19 April through 28 June;	Larvae	0.95	1.10	.480	.089
and 16 and 23 August;	Total IP	0.95	1.10	.486	.092
Locations K2 & K3					

As shown above, mean densities at the surface and at the bottom differ by only about 0.1 larvae/10m3; a non-significant difference. Therefore, we conclude that larvae and total IP were uniformly distributed in the water column during 1988.

3.1.1.7 Dye Studies

The low flow study (riverflow=1650 cfs) conducted when the intake pumps were not operating revealed that the dye plume divided at the riffle just outside of the mouth of Horse Creek. A small part of the plume went through the narrow chute near shore after which it slowly moved through the slackwater area towards the intake. However, most of the dye went around the riffle where it "hugged" the outside of it (Figure 3-6b). After the plume

TABLE 3-9 STATISTICAL COMPARISONS OF LARVAL AND ICHTHYOPLANKTON DENSITIES AMONG FOUR LOCATIONS ON THE KANKAKEE RIVER

Period/Depth/Location		Mean Density (No/10m^3)				Probability	
		K1	K2	K3	K4	Pr	Pt
19 Apr - 14 June (Surface samples only; all locations)	Larvae	1.24	1.32	1.08	1.70	.571	.621
	Total IP	1.24	1.33	1.08	1.70	.573	.625
19 Apr - 28 June (Surface samples only; Locations K1-K3)	Larvae	1.33	1.22	0.99	-	.638	.721
	Total IP	1.35	1.24	0.99	-	.611	.690
19 Apr - 14 June (Depths and Diel periods combined; Locations K1-K3)	Larvae	1.29	1.44	1.07	-	.434	.524
	Total IP	1.30	1.44	1.07	-	.423	.508
19 April - 28 June (Depths and Diel periods combined; Locations K2 & K3 only)	Larvae	-	1.35	1.00	-	.119	.218
	Total IP	-	1.36	1.00	-	.115	.208
19 April - 14 June (Bottom samples only; Locations K1-K3)	Larvae	1.35	1.56	1.05	-	.452	.381
	Total IP	1.35	1.56	1.05	-	.447	.376

TABLE 3-10 WEEKLY ESTIMATES OF FISH EGGS AND LARVAE DRIFT IN HORSE CREEK, 1988.

Week of	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
19 April	0	2,646	0	0	0	2,646
26	0	0	1,575	5,033	1,575	5,033
3 May	0	0	0	38,759	0	38,759
10	0	1,722	721	52,885	721	54,607
17	0	16,877	0	42,525	0	59,402
24	0	23,471	1,372	1,508,577	1,372	1,532,048
31	10,514	37,156	28,819	2,253,545	39,333	2,290,701
7 June	0	3,178	0	89,943	0	93,121
14	0	693	504	16,037	504	16,730
21	0	4,942	448	8,043	448	12,985
28	0	637	0	1,463	0	2,100
5 July	0	1,645	0	546	0	2,191
12	(0)	(1,645)*	(0)	(546)	(0)	(2,191)
19	(0)	(0)	(0)	(1,197)	(0)	(1,197)
26	0	0	0	1,197	0	1,197
2 August	(0)	(382)	(0)	(4,403)	(0)	(4,785)
9	0	763	0	7,609	0	8,372
16	(0)	(382)	(0)	(4,277)	(0)	(4,659)
23	0	0	0	945	0	945
30	0	0	0	175	0	175
6 September	0	0	0	168	0	168
13	(0)	(0)	(0)	(0)	(0)	(0)
Total	10,514	96,139	33,439	4,037,873	43,953	4,134,012

* Values in parenthesis were derived using densities from the week preceding and/or following the week indicated.

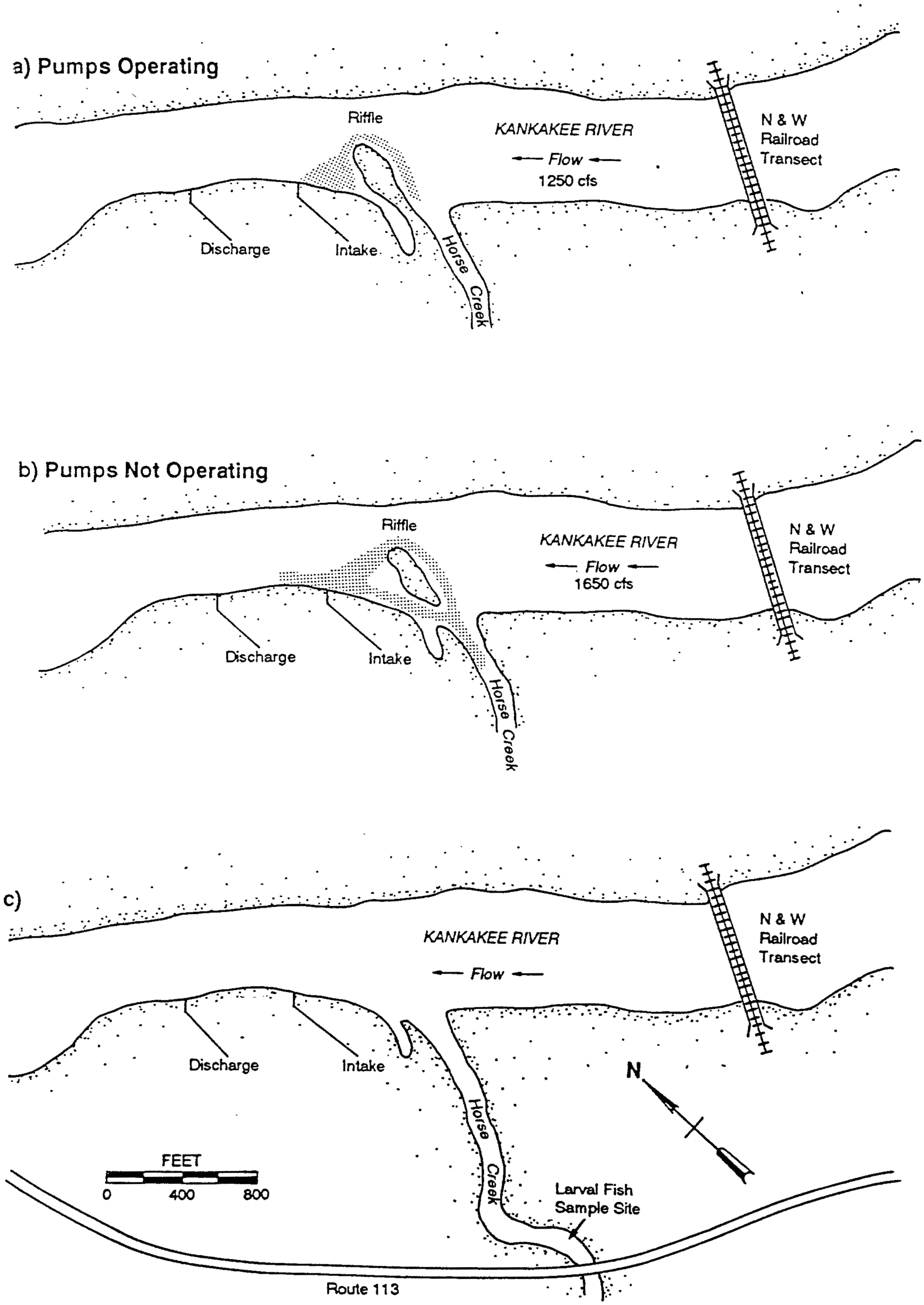


Figure 3-6. Flow of dye from Horse Creek to the Braidwood Station intake structure.

reached the downstream, outer edge of the riffle, it flowed back towards the Intake. The dye did not flow outward and mix with Kankakee River along the right (north) shore (Figure 3-6b). During the low flow study (river flow = 1250 cfs) when the riffle was completely exposed and the intake pumps were operating, the dye again "hugged" the outside of the riffle where it was confined to a narrow band approximately 10 meters wide. When the plume reached the outer edge of the riffle, it flowed around the riffle spreading throughout the slack water area with all the dye eventually being drawn into the upstream intake bay. No dye flowed downstream of the intake bay (Figure 3-6a). It appears that when the riffle is present Horse Creek water is directed towards the intake, regardless of whether or not the intake pumps are operating.

3.1.1.8 Extrapolated Values For Ichthyoplankton

In order to determine what, if any, impact operation of the Braidwood Station might have on ichthyoplankton populations in the Kankakee River it is necessary to estimate the total number of IP entrained by the plant and compare that with the total number in the drift in the river. Estimates of the number of larvae coming out of the cooling lake and from Horse Creek are also useful as they provide an indication of the contribution each of these areas makes to the drift in the river. For all four areas (i.e., Intake, Discharge, Horse Creek, and Kankakee River), the number of eggs, larvae, and total IP was estimated based on multiplying an appropriate mean density times the volume of water passing through that area in one week. The seasonal (i.e., April - September) estimate was the sum of the weekly estimates. Flow volumes for the Intake and Discharge were based on plant operating data supplied by CeCo. Flow volumes for Horse Creek were based on extrapolations of the flow rates we measured each week in Horse Creek. Flow volumes for the Kankakee River were based on data provided by USGS for their gage at Wilmington. Mean density for each area was the mean of all replicates for each day and night period. Separation of day and night data was necessary because the statistical analysis discussed previously showed that density was significantly affected by the time of collection. For each area, the 24-hour estimate was obtained by multiplying the mean density for all the samples collected during the day times the amount of daylight (defined here as 0.5h before sunrise to 0.5h after sunset) on that date and adding that value to the product of the nighttime density times the amount of time it was dark. For example, on 24 May the values for the parameters of interest in Horse Creek were as follows:

Stream flow = 0.93 m^3/sec
Mean daytime larval density = 0.64/10m^3
Mean nighttime larval density = 77.09/10m^3
Amount of daylight = 56,340 sec
Amount of darkness = 30,060 sec

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Based on these values, the total number larvae drifting past that point of Horse Creek on that day would be:

Day	$0.93\ m^3/sec \times 56{,}340\ sec \times 0.64\ larvae/10m^3$ =	3,353 larvae
Night	$0.93\ m^3/sec \times 30{,}060\ sec \times 77.09\ larvae/10m^3$ =	215,511 larvae
	Total =	218,864

The number of eggs in the drift on that date would be calculated in a similar fashion, and total IP would be the sum of the eggs and the larvae. The weekly estimate would be the daily estimate times seven.

At the Intake and in the Kankakee River, the day and night density was the mean of all samples collected during each time period regardless of location or depth. This was done because the statistical analysis (Section 3.1.1.6) showed that neither depth or location affected larval or IP densities, hence it is acceptable to treat all samples in a given time period as replicates.

Horse Creek

Using the procedures described above, we estimate that the Horse Creek drift contained 4,134,012 larvae and 43,953 eggs during the period 19 April to 13 September (Table 3-10). Ninety eight percent of the drifting larvae were collected during the night and 92 percent of the larvae were present during a two week period in late May. Of the larvae present during this two week period, 81 percent were catostomids. The total ichthyoplankton drifting in Horse Creek in 1988 was 10.8 percent of the number drifting in the Kankakee River (Table 3-11).

Kankakee River

We estimate that 37,697,167 larvae and 817,320 eggs were present in the drift from 19 April to 13 September (Table 3-12). Sixty-nine percent of the larvae were collected during the night and 83 percent of the drift occurred in May. Weekly larval drift rates during the 4-week period 10 May - 7 June ranged from 4 to almost 10 million larvae per week.

Intake

Two estimates of entrainment were calculated for the Intake, actual and worst case. The actual case estimate was based on the volume actually pumped during each week of the study, while the worst case estimate was based on pumping 24 hours a day, 7 days a week at the maximum pumping rate (50,000 gpm) (J. Tidmore 1989, CeCo, personal communication) Both calculations used the same diel densities for a given week and both

TABLE 3-11 ESTIMATES OF WEEKLY ICHTHYOPLANKTON ABUNDANCE AT FOUR SITES NEAR THE BRAIDWOOD STATION, 1988.

Week Of	Kankakee River	Horse Creek	Intake	Discharge
5 April	-(a)	-	-	0
12	-	-	-	0
19	60,032	2,646	18,488	19,485
26	147,329	6,608	11,648	25,305
3 May	0	38,759	58,437	1,951
10	5,737,368	55,328	224,784	147,520
17	4,416,230	59,402	948,305	523,000
24	6,726,216	1,533,420	1,943,198	597,197
31	9,521,575	3,430,034	1,600,230	314,135
7 June	4,997,881	93,121	264,602	58,354
14	776,734	17,234	178,602	18,510
21	1,532,069	13,433	431,316	7,271
28	759,087	2,100	185,016	7,791
5 July	624,050	2,191	170,870	-
12	149,919	(2,191)(b)	(102,910)	-
19	1,056,076	(1,197)	282,827	-
26	(782,145)	1,197	*(c)	-
2 August	+(d)	(4,785)	*	-
9	(977,939)	8,372	*	-
16	219,058	(4,659)	31,800	-
23	10,549	945	17,594	-
30	20,230	175	15,255	-
6 September	0	168	35,577	-
13	0	(0)	950	-
Total	38,514,487	4,177,965	6,522,674	1,720,519

(a) Studies at the Kankakee River, Horse Creek, and the Intake did not begin until the week of 19 April. The study at the discharge ended on 28 June.

(b) Values in parenthesis were derived using densities from the week preceeding and/or following the week indicated.

(c) Asterisk indicates that plant decoupled; no pumping took place.

(d) + Indicates that sampling was not conducted this week; estimates for the preceeding and following week were increased to account for the week that was missed.

TABLE 3-12 WEEKLY ESTIMATES OF FISH EGGS AND LARVAE DRIFT IN THE KANKAKEE RIVER, 1988.

Week of	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Egg	Larvae
19 April	0	60,032	0	0	0	60,032
26	0	90,958	0	56,371	0	147,329
3 May	0	0	0	0	0	0
10	0	1,870,372	0	3,866,996	0	5,737,368
17	0	1,090,082	0	3,326,148	0	4,416,230
24	0	2,031,218	11,214	4,683,784	11,214	6,715,002
31	0	1,595,734	12,397	7,913,444	12,397	9,509,178
7 June	32,032	2,781,102	0	2,784,747	32,032	4,965,849
14	0	215,817	0	560,917	0	776,734
21	58,065	816,501	0	657,503	58,065	1,474,004
28	0	455,700	0	303,387	0	759,087
5 July	0	524,188	0	99,862	0	624,050
12	0	102,830	0	47,089	0	149,919
19	703,612	182,231	0	170,233	703,612	352,464
26	0	226,443	0	555,702	0	782,145
2 August	*	*	*	*	*	*
9	0	182,448	0	795,491	0	977,939
16	0	16,149	0	202,909	0	219,058
23	0	10,549	0	0	0	10,549
30	0	0	0	20,230	0	20,230
6 September	0	0	0	0	0	0
13	0	0	0	0	0	0
Total	793,709	11,652,354	23,611	26,044,813	817,320	37,697,167

* Indicates that sampling was not conducted this week; estimates for the preceeding and following week were increased to account for the week that was missed.

were extrapolated based on actual seconds of daylight and darkness as previously discussed. We estimate that 5,836,638 larvae and 686,036 eggs were drawn into the intake system during the study period. (Table 3-13). Estimates derived using the worst case scenario indicate that 11,234,263 larvae and 995,888 eggs would have been entrained if pumping had occurred continuously (Table 3-14). The actual ichthyoplankton entrainment estimate represents 16.9 percent of the ichthyoplankton in the Kankakee River drift (Table 3-11), whereas 29.2 percent of the ichthyoplankton in the Kankakee River drift would be entrained under worst case conditions (Tables 3-11 and 3-14).

Discharge

Weekly estimates of ichthyoplankton in the Discharge were calculated two ways: 1) based on the volume actually pumped each week and 2) based on a worst case scenario that assumed that the maximum release rate of 28 MGD was maintained for the entire week (J. Tidmore 1989, CeCo, personal communication). We estimate that 1,394,405 larvae and 326,114 eggs were actually discharged into the river from 5 April through 28 June (Table 3-15). If maximum discharge had occurred during this period, 1,955,233 larvae and 467,185 eggs would have been discharged into the river (Table 3-16).

TABLE 3-13 ACTUAL CASE ESTIMATES[(a)] OF WEEKLY ENTRAINMENT OF FISH EGGS AND LARVAE AT THE BRAIDWOOD STATION INTAKE, 1988.

Week of	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Egg	Larvae
19 April	0	9,658	8,830	0	0	18,488
26	0	5,412	265	6,236	265	11,648
3 May	0	12,948	0	45,489	0	58,437
10	0	35,385	0	189,399	0	224,784
17	400,474	85,877	0	461,954	400,474	547,831
24	209,951	73,356	20,885	1,639,006	230,836	1,712,362
31	0	291,811	34,693	1,273,726	34,693	1,565,537
7 June	4,674	61,934	2,878	195,116	7,522	257,050
14	0	68,044	1,156	109,402	1,156	177,446
21	2,836	108,494	5,561	314,425	8,397	422,919
28	0	92,588	366	92,092	366	184,650
5 July	0	56,410	475	113,985	475	170,395
12	(327)[(b)]	(25,502)	(107)	(76,974)	(434)	(102,476)
19	1,388	54,118	0	227,321	1,388	281,439
26	-(c)	-	-	-	-	-
2 August	-	-	-	-	-	-
9	-	-	-	-	-	-
16	0	2,666	0	29,134	0	31,800
23	0	1,291	0	16,303	0	17,594
30	0	3,241	0	12,014	0	15,255
6 September	0	0	0	35,577	0	35,57713
13	0	0	0	950	0	950
Total	619,650	988,708	66,386	4,847,933	686,035	5,836,638

(a) Based on total volume pumped each week.
(b) Values in parenthesis were derived using densities from the week preceding and/or following the week indicated.
(c) Dash indicates that plant was decoupled and no pumping took place.

TABLE 3-14 WORST CASE ESTIMATES[a] OF WEEKLY LARVAL FISH AND EGG ENTRAINMENT AT THE BRAIDWOOD STATION INTAKE, 1988.

Week of	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Egg	Larvae
19 April	0	39,900	0	35,854	0	75,754
26	0	29,127	1,442	33,936	1,442	63,063
3 May	0	66,486	0	234,416	0	300,902
10	0	77,322	0	413,378	0	490,700
17	577,696	123,879	0	666,386	577,696	790,265
24	306,383	107,051	30,198	2,370,004	336,581	2,477,055
31	0	327,992	39,711	1,461,040	39,711	1,789,032
7 June	10,178	134,876	6,146	416,682	16,324	551,558
14	0	110,698	1,841	174,538	1,841	285,236
21	1,274	128,799	6,734	380,639	8,008	509,418
28	0	316,827	1,232	309,134	1,232	625,961
5 July	0	148,106	1,239	298,144	1,239	446,250
12	(1,866)[b]	(146,801)	(620)	(455,977)	(2,486)	(602,778)
19	3,731	145,495	0	613,809	3,731	759,304
26	-	-	-	-	-	-
2 August[c]	(5,597)	(228,743)	0	(1,036,392)	(5,597)	(1,265,135)
9	-	-	-	-	-	-
16	0	7,000	0	77,119	0	84,119
23	0	4,571	0	58,800	0	63,371
30	0	3,360	0	12,285	0	15,645
6 September	0	0	0	37,072	0	37,072
13	0	0	0	1,645	0	1,645
Total	906,725	2,147,013	89,163	9,087,250	995,888	11,234,263

(a) Based on total volume pumped each week.
(b) Values in parenthesis were derived using densities from the week preceding and/or following the week indicated.
(c) The estimates on 2 August are for the period 26 July to 9 August when the plant was decoupled. The estimates were derived using the drift rates on 19 July and 16 August.

TABLE 3-15 WEEKLY ACTUAL CASE ESTIMATES OF FISH EGGS AND LARVAE DISCHARGED INTO THE KANKAKEE RIVER BY THE BRAIDWOOD STATION, 1988

Week or	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
5 April	0	0	0	0	0	0
12	0	0	0	0	0	0
19	0	19,485	0	0	0	19,485
26	0	19,924	0	5,381	0	25,305
3 May	0	0	0	1,951	0	1,951
10	0	97,641	0	49,879	0	147,520
17	7,326	241,414	23,857	250,403	31,183	491,817
24	53,387	231,116	27,820	284,874	81,207	515,990
31	18,692	32,539	181,066	81,838	199,758	114,377
7 June	0	28,568	10,599	19,187	10,599	47,755
14	0	7,471	0	11,039	0	18,510
21	0	4,765	0	2,506	0	7,271
28	1,430	1,430	1,937	2,994	3,367	4,424
Total	80,835	684,353	245,279	710,052	326,114	1,394,405

TABLE 3-16 MAXIMUM WEEKLY ESTIMATES OF FISH EGGS AND LARVAE DISCHARGED INTO THE KANKAKEE RIVER BY THE BRAIDWOOD STATION, 1988.

Week of	Day		Night		Combined	
Date	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
5 April	0	0	0	0	0	0
12	0	0	0	0	0	0
19	0	26,707	0	0	0	26,707
26	0	27,137	0	7,330	0	34,467
3 May	0	0	0	2,745	0	2,745
10	0	139,588	0	71,308	139,588	210,896
17	10,126	333,689	32,976	346,115	43,102	679,804
24	74,742	323,562	38,948	398,824	113,690	722,386
31	26,840	46,722	259,992	117,511	286,832	164,233
7 June	0	38,273	14,199	25,705	14,199	63,978
14	0	9,941	0	14,689	0	24,630
21	0	8,576	0	4,511	0	13,087
28	3,976	3,976	5,386	8,324	9,632	12,300
Total	115,684	958,171	351,501	997,062	467,185	1,955,233

3.1.2 MACROINVERTEBRATE DRIFT

A total of 23,509 macroinvertebrates representing 161 taxa were identified in the 194 drift collections analyzed from the Kankakee River, Horse Creek, the Intake, and the Discharge (Table 3-17). Kankakee River collections yielded 132 taxa; the Intake - 121 taxa; Horse Creek - 107 taxa; and the Discharge - 61 taxa. The predominate taxa for all four sites combined included: Ephemeroptera (mayflies), Chironomidae (midges), Naididae (segmented worms), Trichoptera (caddisflies), and Hemiptera (water bugs). These taxa accounted for 88 percent of the organisms collected. The Ephemeropterans comprised nearly 51 percent of the total drift (Table 3-18).

3.1.2.1 Kankakee River

A total of 13,056 organisms representing 132 taxa were identified from 130 drift samples (Table 3-17). Five groups accounted for 89.9 percent of the total catch: Ephemeroptera (58.5 percent); Chironomidae (17.2 percent); Naididae (7.2 percent); Hemiptera (3.5 percent); and Trichoptera (3.5 percent) (Table 3-18). Of the 132 taxa identified, 16 where collected exclusively in the Kankakee River (Table 3-17).

The ephemeropteran's (mayflies) were represented primarily by Caenidae - Caenis sp. (15.7 percent of the mayflies), Ephemeridae - Hexagenia sp. (11.9 percent), Heptageniidae - Heptagenia maculipennis (11.7 percent), Baetidae - Baetis sp. (9.7 percent), Polymitarcyidae - Ephoron sp. (9.6 percent), and Baetidae - Pseudocloen sp. (7.7 percent). Chronomidae was the most diverse family collected in the Kankakee River, being represented by 37 taxa (Table 3-17). The predominant Chironomidae were the following: Procladius sp. (20.0 percent of the Chironomids), Ablabesmyia sp. (14.7 percent), Polypedilum convictum (10.2 percent), Rheotanytarsus (9.2 percent), and Labrundinia sp. (9.1 percent). Naididae was the second most diverse family collected and was represented by 14 species, of which Paranais frici (36.8 percent) and Stylaria lacustris (32.3 percent) were the most abundant. The hemipterans were represented in the drift by two families - Belastomatidae and Corixidae. The corixids comprised 99.6 percent of the hemipterans. The trichopterans were represented by 6 families and 11 taxa in the Kankakee River drift. The dominate trichopterans included Oxyethira sp. (50.5 percent) and Hydropsyche phalerata (24.5 percent) (Appendix C).

The mean macroinvertebrate density (day and night combined) for the Kankakee River was 15.7 organisms per $10m^3$, ranging from 1.5 to 45.2 organisms per $10m^3$ (Table 3-19). For the entire study, night densities were consistently higher than day densities. Night macroinvertebrate densities ranged from 2.4 to 83.6 organisms per $10m^3$ and averaged 26.5 organisms per $10m^3$, whereas day densities ranged from 0.2 to 34.6 organisms per $10m^3$ and averaged 5.1 organisms per $10m^3$, five-fold lower than at night. Ephemeropterans were the

TABLE 3-17 THE DISTRIBUTION OF DRIFTING MACROINVERTEBRATES AMONG SAMPLING SITES NEAR THE BRAIDWOOD STATION, 1988

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Cnidaria				
Hydra sp.	X	X	X	X
Platyhelminthes (flatworms)				
Planariidae	X	X	X	X
Nematoda (roundworms)	X	X	X	X
Annelida (segmented worms)				
Oligochaeta				
Enchytracidae			X	X
Nadidae		X	X	X
Chaetogaster diaphanus		X	X	X
Dero digitata		X	X	X
Dero sp.		X	X	X
Nais bretscheri	X			X
Nais communis		X	X	X
Nais elinguis			X	X
Nais pardalis	X	X	X	X
Nais variabilis	X	X	X	X
Nais sp.		X		
Ophidonais serpentina	X	X	X	X
Paranais frici	X	X	X	X
Piguetiella michiganensis	X	X	X	
Pristina longiseta leidyi		X		X
Pristina sp.			X	
Salvina appendiculata		X	X	X
Stylaria lacustris	X	X	X	X
Vejodvskyella intermedia			X	X
Tubificidae				
Branchiura sowerbyi			X	X
Limnodrilus hoffmeisteri			X	X
Immature w/o cap. chaetae			X	X
Hirudinea (leeches)				
Glossiphoniidae			X	X
Tardigrada (water bears)		X		
Arthropoda				
Crustacea				
Isopoda (pill bugs)				
Ascellus sp.		X	X	
Amphipoda (scuds)				
Talitridae				
Hyalella azteca		X	X	X
Gammaridae				
Crangonx sp.	X		X	X
Gammarus sp.		X		X
Decapoda				
Astacidae	X		X	
Acari				
Hydracarina (water mites)	X	X	X	X

Table 3-17 (Cont)

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Insecta				
Ephemeroptera (mayflies)				
Baetidae			X	
Baetis sp.	X	X	X	X
Callibaetis sp.		X	X	X
Centroptilum sp.		X	X	X
Pseudocloeon sp.	X	X	X	X
Oligoneuriidae				
Isonychia	X	X	X	X
Heptageniidae				X
Heptagenia flavescens				X
Heptagenia maculipennis	X	X	X	X
Heptagenia sp.				X
Pseudiron sp.	X		X	X
Stenacron sp.	X	X	X	X
Stenonema intergrum			X	X
Stenonema pulchellum	X		X	X
Stenonema terminatum	X			X
Stenonema tripunctatum		X		
Stenonema sp.	X	X	X	X
Ephemerellidae				
Ephemerella needhami				X
Serratella fisoni				X
Tricorythidae				
Tricorythodes sp.	X	X	X	X
Caenidae				
Brachycercus sp.			X	X
Caenis sp.	X	X	X	X
Baetiscidae				
Baetisca sp.			X	X
Baetisca bajkovi			X	X
Potamanthidae				
Potamanthus sp.	X	X	X	X
Ephermeridae	X			X
Ephemera sp.		X		X
Hexagenia sp.		X	X	X
Palingeniidae				
Pentagenia vittigera				X
Polymitarcyidae				
Ephoron sp.		X	X	X
Odonata (dragonflies & damselflies)				
Gomphidae				X
Aeschnidae			X	X
Libellulida		X	X	
Coenagrionidae	X	X	X	X
Argia sp.		X	X	X
Enallagma sp.	X		X	X
Plecoptera (stoneflies)			X	X
Perlidae	X	X	X	X
Perlesta sp.			X	X

Table 3-17 (Cont)

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Perlodidae				
Isoperla sp.			X	X
Hemiptera (water bugs)				
Gerridae			X	
Metrobates sp.		X		
Belostomatidae		X	X	X
Corixidae	X	X	X	X
Megaloptera (alderflies, dobsonflies, & fishflies)				
Corydalidae				
Corydalus cornatus				X
Neuroptera (spongilla flies)				
Sisyridae				
Climacia sp.		X		X
Trichoptera (caddisflies)		X	X	X
Philopotamidae				
Chimarra obscura		X	X	
Polycentropodidae				X
Cyrnellus fraternus	X		X	
Neureclipsis sp.	X		X	
Polycentropus sp.		X		X
Hydropsychidae		X	X	X
Cheumatopsyche sp.		X	X	X
Hydropsyche betteni (near)			X	
Hydropsyche orris (near)	X			
Hydropsyche phalerata (near)	X	X	X	X
Hydropsyche sp.		X	X	X
Potamyia flava	X		X	X
Symphitopsyche bifida group			X	
Symphitopsyche sp.		X		X
Rhyacophilidae				
Protoptila sp.		X		X
Hydropitilidae	X	X		X
Hydroptila sp.	X	X	X	X
Mayatrichia ayama				X
Oxyethira sp.		X	X	X
Leptoceridae				
Nectopsyche sp.	X	X	X	X
Oecetis sp.		X	X	X
Triaenodes sp.				X
Lepidoptera (aquatic caterpillars)				
Pyralidae			X	X
Paraponyx sp.			X	X
Petrophila sp.		X		X
Coleoptera (beetles)				
Gyrinidae				
Dineutus sp.				X
Gyrinus sp.		X		
Haliplidae				
Peltodytes sp.		X	X	X

Table 3-17 (Cont)

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Dytiscidae				
Laccophilus sp.				X
Hydrophilidae				X
Enochrus sp.				X
Tropisternus sp.			X	X
Psephenidae				
Psephonus herricki		X		
Elmidae				
Dubiraphra sp.		X	X	X
Stenelmis sp.	X	X	X	X
Macronychus glabratus	X	X	X	X
Diptera (two-winged flies)				
Tipulidae				
Tipula sp.		X		
Culicidae			X	X
Anopheles sp.		X		
Culex sp.		X	X	
Chaoboridae				
Chaoborus punctipennis	X	X	X	X
Chaoborus sp.	X			
Psychodidae				
Psychoda sp.		X	X	X
Ceratopogonidae		X	X	X
Simuliidae		X	X	X
Simulium sp.	X	X	X	X
Chironomidae				
Chironominae				
Chironomus sp.		X	X	X
Cladotanytarsus sp.		X	X	
Cryptochironomus sp.	X	X	X	X
Cryptotendipes sp.		X	X	X
Demicryptochironomus sp.			X	X
Dicrotendipes sp.	X	X	X	X
Endochironomus sp.		X		
Glyptotendipes sp.		X		
Harnischia sp.	X		X	X
Microtendipes sp.		X	X	X
Parachironomus cf. *frequens*			X	
Parachironomus sp.	X	X	X	X
Paracladopelma sp.		X		X
Paralauterborniella sp.		X		
Paratanytarsus sp.		X	X	X
Paratendipes sp.		X	X	
Polypedilum convictum	X	X	X	X
Polypedilum scalaenum		X	X	X
Polypedilum simulans			X	X
Polypedilum sp.	X	X	X	X
Rheotanytarsus sp.	X	X	X	X
Stempellina sp.		X		
Stenochironomus sp.		X	X	X

Table 3-17 (Cont)

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Stictochironomus sp.		X	X	
Tanytarsus sp.	X	X	X	X
Tribelos sp.		X	X	X
Zavrelia sp.				X
Tanypodinae				
Ablabesmyia sp.	X	X	X	X
Coelotanypus sp.	X		X	X
Labrundinia sp.		X	X	X
Larsia sp.		X	X	X
Procladius sp.	X	X	X	X
Tanypus sp.		X	X	
Thienemannimyia sp.		X	X	X
Thienemannlmyia series	X	X	X	X
Orthocladinae				
Corynoneura sp.				X
Cricotopus bicintus group	X	X	X	X
Cricotopus sylvestris group	X		X	X
Cricotopus tremulus group	X	X	X	X
Cricotopus trifascia group		X	X	X
Cricotopus sp.	X	X	X	X
Eukiefferiella sp.			X	
Hydrobaenus sp.	X	X	X	
Limnophyes sp.		X		
Nanocladius sp.	X	X	X	X
Orthocladius sp.	X	X	X	X
Parakiefferiella sp.	X	X	X	X
Rheocricotopus sp.		X	X	X
Smittia sp.				X
Thienemanniella sp.		X	X	X
Tventia discoloripes group	X			X
Diamesinae				
Diamesa sp.		X	X	
Stratiomyiidae		X	X	X
Tabanidae				
Tabanus sp.				X
Empididae			X	
Mollusca				
Gastropoda (snails)				
Pleuroceridae				X
Goniobasis sp.				X
Pleurocerca sp.				X
Physidae				
Physa sp.	X	X	X	X
Lymnaeidae				
Lymnaea sp.	X		X	
Planorbidae				X
Gyraulus sp.		X	X	X
Helisoma sp.		X		
Ancylidae				
Ferrissia sp.			X	X

Table 3-17 (Cont)

Taxa	Discharge	Horse Cr.	Intake	Kankakee R.
Pelecypoda (clams)				
Sphaeriidae	X	X	X	
Corbiculidae				
Corbicula fluminea		X		X
Total Taxa/Location	60	107	121	132
Total Taxa	161			

TABLE 3-18 RELATIVE ABUNDANCE OF THE DOMINANT MACROINVERTEBRATE TAXA COLLECTED NEAR THE BRAIDWOOD STATION, 1988

Taxa	Discharge	Horse Creek	Intake	Kankakee River
Hydra	1.3	0.5	0.3	1.4
Planariidae	0.7	0.4	0.3	0.2
Nematoda	0.1	0.2	0.1	<0.1
Tardigrada		0.1		
Naididae	2.4	21.6	12.9	7.2
Other Oligochaeta			0.3	0.2
Hyalella azteca		9.9	1.4	1.9
Other Crustacea	0.1	0.2	0.1	<0.1
Decapoda		0.2		<0.1
Hydracarina (acarina)	0.8	0.4	1.0	0.5
Ephemeroptera	9.8	17.9	46.0	58.5
Odonata	0.1	0.5	2.7	1.9
Plecoptera	0.1	0.1	0.2	0.2
Hemiptera	0.1	1.3	1.9	3.5
Megaloptera				<0.1
Neuroptera		1.0		<0.1
Trichoptera	19.6	3.8	3.6	3.5
Lepidoptera		0.1	0.2	0.1
Coleoptera	0.7	3.9	0.6	1.2
Chironomidae	59.4	29.2	23.5	17.2
Other Diptera	4.0	4.2	0.9	0.6
Physa sp.	0.5	5.0	3.4	0.9
Other Gastropoda	0.1	0.1	0.6	0.4
Pelecypoda	0.2	0.2	<0.1	0.1

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TABLE 3-19 DIEL DIFFERENCES IN MACROINVERTEBRATE DENSITIES DURING COLLECTIONS IN THE KANKAKEE RIVER, 1988

Date	Day ($No./10m^3$)	Night ($No./10m^3$)	Mean ($No./10m^3$)
19 April	4.8	12.4	8.6
26	2.9	6.8	4.9
3 May	2.4	12.4	7.4
10	5.0	5.8	5.4
17	5.0	19.0	12.0
24	6.8	83.6	45.2
31	34.6	39.6	37.1
7 June	3.2	33.8	18.5
14	1.0	79.8	40.4
21	1.4	45.6	23.5
28	0.2	20.2	10.2
5 July	0.4	12.0	6.2
12	0.6	2.4	1.5
19	2.6	30.6	16.6
26	0.7	72.1	36.4
2 August	*	*	*
9	2.3	*	*
16	6.0	21.2	13.6
23	1.3	4.3	2.8
30	18.5	10.4	14.5
6 September	5.2	21.2	13.2
13	1.8	22.4	12.1
MEAN	5.1	26.5	15.7

* Denotes no samples collected

most abundant group of macroinvertebrates collected during 15 of the 20 sampling dates when both day and night samples were collected. During the period 24 May through 21 June and on 26 July they comprised greater than 59 percent of the mean daily density (Appendix D). Macroinvertebrate drift density was more uniformly distributed over the study period than was the density of ichthyoplankton (Table 3-19).

3.1.2.2 Horse Creek

A total of 1,612 organisms representing 107 taxa were identified from 18 drift samples (Table 3-17). Chironomidae (29.2 percent), Naididae (21.6 percent), Ephemeroptera (17.9 percent), and Hyalella azteca (9.9 percent) accounted for 78.6 percent of the drifting macroinvertebrate organisms in Horse Creek (Table 3-18).

The chironomids were represented in the drift by 37 taxa (Table 3-17). Tanytarsus sp. (14.9 percent), Polypedilum convictum (13.6 percent), Orthocladius sp. (10.4 percent), Procladius sp. (7.7 percent), Parakiefferiella sp. (7.0 percent), and Larsia sp. (6.8 percent) were the predominant chironomidae collected (Appendix C). The predominant species of Naididae collected included Stylaria lacustris (42.0 percent), Nais varabilis (14.1 percent), Chaetogaster diaphanus (13.5 percent), and Nais pardalis (10.1 percent). The ephemeropterans collected in Horse Creek were represented by 8 families which included 15 taxa (Table 3-17). The most commonly encountered ephemeropterans were: Baetidae - Baetis sp. (24.7 percent); Caenidae - Caenis sp. (21.9 percent); Heptageniidae - Heptagenia maculipennis (13.3 percent); and Tricorythidae - Tricorythodes sp. (11.5 percent). Taxa exclusive to Horse Creek were Tardigrada (water bears); Ephemeroptera - Stenonema tripunctatum; Hemiptera - Metrobates sp.; Coleoptera - Gyrinus sp. and Psephenus herricki; Diptera - Tipula sp. and Anopheles sp.; Chironomidae - Endochironomus sp., Glyptotendipes sp., Paralauterborniella sp., Stempellina sp., and Limnophyes sp.; and Gastropoda - Helisoma sp.

Because we typically alternated between day and night sampling for macroinvertebrates, diel comparisons are possible on only two dates, 3 May and 23 August. On these two dates, drift densities at night were 6.6 times higher than during the day. (Appendix D).

3.1.2.3 Intake

A total of 7,190 organisms representing 121 taxa were identified from 36 drift samples collected at the Intake (Table 3-17). Three macroinvertebrate groups accounted for nearly 83 percent of the total: Ephemeroptera (46.0 percent), Chironomidae (23.5 percent), Naididae (12.9 percent) (Table 3-18). Eleven taxa were collected exclusively at the Intake: Ephemeroptera - Ephemerella needhami and Pentagenia vittigera; Odonata - Gomphidae; Megaloptera - Corydalus cornutus; Trichoptera - Triaenodes sp.; Coleoptera - Dineutus sp.;

Chironomidae - Zavrelia sp., Corynoneura sp., and Tabanus sp.; and Gastropoda - Goniobasis sp. and Pleurocerca sp. (Table 3-17).

The Ephemeroptera were represented by primarily Tricorythidae - Tricorythodes sp. (21.9 percent), Baetidae - Baetis sp. (21.8 percent), Ephemeridae - Hexagenia sp. (14.2 percent), and Baetidae - Pseudocloeon (13.4 percent). The family chironomidae, the most diverse group, was represented by 37 taxa, the same number of taxa as in the river and at the Intake. The predominate chironomids included: Polypedilum convictum (31.5 percent); Procladius sp. (12.3 percent); Larsia sp. (8.2 percent); Ablabesmyia sp. (7.0 percent) and immature Polypedilum sp. (6.0 percent). Four species of Naididae comprised nearly 93 percent of the total number of naidids; these four species were Stylaria lacustris (68.3 percent), Nais variabilis (9.6 percent), Paranais frici (9.0 percent) and Chaetogaster diaphanus (5.7 percent) (Appendix C).

Of the 121 taxa collected at the Intake, 75 taxa were common among the Intake, the Kankakee River, and Horse Creek (Table 3-17). The species composition of the Intake appears to be a combination of Horse Creek and Kankakee River taxa. In addition to the 11 taxa unique to the Intake, several taxa were present at only two of the three locations (Table 3-17). Table 3-20 shows that 26 taxa were common between the Intake and Kankakee River whereas only 9 taxa were common between the Intake and Horse Creek. Similarly, a comparison of the relative abundance of the various macroinvertebrate groups shows that the relative abundance at the Intake is more closely aligned with that in the river than in Horse Creek. For example, the relative abundance of Ephemeropterans is similar at the Intake and the Kankakee River but both are much higher than in Horse Creek (Table 3-18). This suggests that for many taxa, certainly ephemeropterans, the species composition at the Intake is influenced more by drift in the Kankakee River than by drift originating in Horse Creek. However, this trend is not evident in all predominant macroinvertebrate groups. For example, the abundance of trichopterans and chironomids is relatively similar among the three sites; the relative abundance of these groups at the Intake is intermediate between their abundance in Horse Creek and in the Kankakee River.

Macroinvertebrates were present in all samples analyzed. The mean density (diel periods combined) for the study was 29.5 organisms per $10m^3$, ranging from 5.7 to 118.8 organisms per $10m^3$ (Table 3-21). The mean at the Intake (29.5) was approximately double what it was in the river (15.7). On all sampling dates but two (7 June and 6 September), densities were higher at night than they were during the day (Table 3-21). Day densities ranged from 1.0 to 55.2 organisms per $10m^3$ and averaged 12.2 organisms per $10m^3$. Night densities ranged from 8.7 to 203.2 organisms per $10m^3$ and averaged 46.8 organisms per $10m^3$. Peak mean density (diel periods combined) for the Intake occurred on 19 July (118.8 organisms/$10m^3$). This peak was attributable to mayflies, mainly Tricorythodes sp. (32.5/$10m^3$) and Hexagenia sp. (28.7/$10m^3$) (Appendix D).

TABLE 3-20 A COMPARISON OF MACROINVERTEBRATE TAXA COMMON BETWEEN THE BRAIDWOOD INTAKE AND THE KANKAKEE RIVER OR HORSE CREEK, 1988

Taxa	Intake	Kankakee River	Horse Creek
Enchytracidae	X	X	
Nais elinguis	X	X	
Vejodvskyella intermedia	X	X	
Branchiura sowerbyi	X	X	
Limnodrilus hoffmeisteri	X	X	
Glossiphoniidae	X	X	
Acellus sp.	X		X
Cragonyx sp.	X	X	
Pseudiron sp.	X	X	
Stenonema intergrum	X	X	
S. pulchellum	X	X	
Brachycercus sp.	X	X	
Baetisca sp.	X	X	
B. bajoleovi	X	X	
Aeschnidae	X	X	
Libellulidae	X	X	
Enallagma	X	X	
Perlesta sp.	X	X	
Isoperla sp.	X	X	
Chimarra obscura	X		X
Potamyia flava	X	X	
Paraponyx sp.	X	X	
Tropisternus sp.			
Culex sp.	X		X
Demicrytochirononus	X	X	
Harnischia sp.	X	X	
Paratendipes sp.	X		X
Polypedilum simulans	X	X	
Stictochironomus sp.	X		X
Coelotanypus sp.	X	X	
Tanypus sp.	X		X
Cricotopus sylvestris	X	X	
Hydrobaenus sp.	X		X
Diamesa sp.	X		X
Ferrissia sp.	X	X	
Sphaeriidae	X		X

TABLE 3-21 DENSITY OF MACROINVERTEBRATES COLLECTED AT BRAIDWOOD STATION INTAKE, 1988

	DENSITY (No./10m^3)		
	Day	Night	Mean
19APR	6.7	18.8	12.8
26	4.3	12.8	8.6
3MAY	2.8	13.7	8.3
10	4.7	23.1	13.9
17	1.8	40.4	21.1
24	18.5	158.4	88.5
31	8.3	49.7	29.0
7JUN	22.5	8.9	15.7
14	1.0	11.2	6.1
21	4.2	41.7	23.0
28	2.7	8.7	5.7
5JUL	5.5	52.5	29.0
12	-(a)	-	-
19	34.4	203.2	118.8
26	-	-	-
2AUG	-	-	-
9	-	-	-
16	7.1	28.7	17.9
23	9.9	32.1	21.0
30	7.7	66.6	37.2
6SEP	55.2	29.6	42.4
13	21.7	42.8	32.3
MEAN	12.2	46.8	29.5

(a) No samples collected - plant decoupled.

3.1.2.4 Discharge

A total of 1,651 organisms representing 60 taxa was identified from 10 drift samples collected in the Discharge (Table 3-17). The dominant groups of macroinvertebrates collected in the Discharge were Chironomidae (59.4 percent), Trichoptera (19.6 percent) and Ephemeroptera (9.8 percent) (Table 3-18). Of the 60 taxa collected, 44 were also present at the three other sites. Only Hydropsyche orris was unique to the discharge.

Chironomidae, the most diverse family collected, was represented by 19 taxa; Dicrotendipes sp. (40.4 percent), Parakiefferiella sp. (15.7 percent) and immature Cricotopus sp. (11.8 percent) were the three most abundant chironomids collected. The trichopterans were represented almost entirely by Potamyia flava (86.4 percent), with Cyrnellus fraternus comprising 10.5 of the remaining 13.6 percent. Ephemeropteran numbers were also dominated by a single taxa, Pseudocloeon sp. of the family Baetidae, which comprised 61.5 percent of the total number of ephemeropterans (Appendix C).

Macroinvertebrates were present in all samples collected. The mean density (diel periods combined) for the 10 samples collected was 27.3 organisms per $10m^3$, ranging from 18.6 to 64.7 organisms per $10m^3$:

	Density (No./10m3)		
Date	Day	Night	Mean
12 April	30.5	26.6	28.6
3 May	13.3	23.9	18.6
17 May	6.5	42.9	24.7
7 June	13.7	37.9	25.8
28 June	18.0	111.4	64.7
Mean	16.4	48.5	27.3

With the exception of 12 April, macroinvertebrate densities were consistently higher at night than they were during the day. The mean night density (48.5) was approximately 3 times higher than the mean day density (16.4). Day densities ranged for 6.5 to 30.5 organisms per $10m^3$, whereas night densities ranged from 23.9 to 111.4 organisms per $10m^3$.

On 12 April, the midge Parakiefferiella dominated the drift comprising 52.4 percent of the mean density. This was the only date that Parakiefferiella was present in the drift (Appendix D). The caddisfly Potamyia flava was present in the drift on all dates. It dominated the drift on 3 May ($9.4/10m^3$) and was the second most abundant taxa collected on 12 April ($8.2/10m^3$). Potamyia flava was also common on 7 June ($2.5/10m^3$) and 28 June ($4.9/10m^3$). On 17 May, the mayfly Pseudocloen sp. and the caddisfly Cyrnellus fraternus dominated the drift, 37.7 and 3.1 percent, respectively. These two taxa were also present on 7 and 28 June, but were less abundant. The midges Cricotopus sp. (immatures) and Dicrotendipes sp. were the two most abundant taxa collected on 7 June (7.1 and 5.5 organisms per $10m^3$, respectively). Dicrotendipes sp. also dominated the drift on 28 June ($36.5/10m^3$), comprising nearly 57 percent of the drift (diel periods combined) and 65.3 percent of the night drift. It was the most abundant taxa collected on any one date. Other predominate taxa collected on 28 June included the midges Parachironomus ($9.3/10m^3$) and Rheotanytarsus ($3.1/10m^3$); and the phantom midge, Chaoborus punctipennis ($2.5/10m^3$). The total number of taxa collected ranged from 16 on 12 April to 30 on 3 and 17 May. (Appendix D).

3.1.2.5 Extrapolated Values For Macroinvertebrates

In order to determine what, if any, impact operation of the Braidwood Station might have on macroinvertebrate populations in the Kankakee River, it is necessary to estimate the total number of macroinvertebrates entrained by the plant and compare that with the total number in the drift in the river. Estimates of macroinvertebrates coming out of the cooling lake and from Horse Creek are also useful as they provide an indication of the contribution each of these areas makes to the drift in the river. For all four areas (i.e. Intake, Discharge, Horse Creek, and Kankakee River), the number of macroinvertebrates was estimated according to the procedures described in Section 3.1.1.7.

Kankakee River

We estimate that approximately 666 million organisms were present in the macroinvertebrate drift in the Kankakee River from 19 April through 13 September (Table 3-22). Night drift accounted for nearly 69 percent of the total drift. Approximately 36 percent of the total drift occurred during the weeks of 24 and 31 May. During this period, Ephemeropterans (primarily Heptagenia maculipennis, Baetis sp., Pseudocloeon sp., and Ephoron sp.) comprised 75 to 77 percent of the total drift.

Intake

The number of macroinvertebrates entrained by the Braidwood Station intake was estimated in 2 ways: 1) Actual case - based on actual volume pumped during each week sampled in 1988 (see Table 2-3); and 2) Worst case - based on the maximum pumping rate (50,000 gpm) for 24 hours a day, seven days a week. The actual case estimate was 50,299,133 organisms or 7.6 percent of the total river drift (Table 3-23). The worst case estimate was 123,807,125 organisms or 18.6 percent of the total river drift (Table 3-24).

TABLE 3-22 WEEKLY ESTIMATES OF MACROINVERTEBRATE DRIFT IN THE KANKAKEE RIVER NEAR THE BRAIDWOOD STATION, 1988

Week Of	Day Drift	Night Drift	Total Drift
19 April	28,816,907	48,773,438	77,590,345
26	13,188,525	19,167,127	32,355,652
3 May	9,543,443	29,062,201	38,605,644
10	18,703,692	12,189,450	30,893,142
17	13,975,416	28,595,854	42,571,270
24	15,876,161	104,139,385	120,015,546
31	77,763,931	44,639,952	122,403,883
7 June	4,880,792	24,900,638	29,781,430
14	1,027,705	39,611,887	40,639,592
21	1,270,115	19,855,647	21,125,762
28	123,165	6,008,282	6,131,447
5 July	246,680	3,631,222	3,877,902
12	268,254	538,181	806,435
19	1,316,112	8,014,125	9,330,237
26	377,405	20,867,630	21,245,035
2 August	(540,785)*	(9,430,610)	(9,971,395)
9	902,447	10,767,890	11,670,337
16	3,229,632	7,051,968	10,281,600
23	685,601	1,477,161	2,162,762
30	9,090,746	3,506,720	12,597,466
6 September	2,738,736	8,323,462	11,062,198
13	1,031,303	9,925,818	10,957,121
Total	205,597,553	460,478,648	666,076,201

*Values in parenthesis were derived using the mean of the density on 26 July and 9 August.

TABLE 3-23 ESTIMATES OF THE NUMBER OF MACROINVERTEBRATES ACTUALLY ENTRAINED AT THE BRAIDWOOD STATION, 1988

Week Of	Day Drift	Night Drift	Total Drift
19 April	184,886	345,856	530,742
26	93,088	169,834	262,922
3 May	64,738	186,029	250,767
10	259,858	718,410	978,268
17	153,047	1,849,648	2,002,695
24	1,559,877	7,191,650	8,751,527
31	927,981	2,736,885	3,664,866
7 June	1,314,636	256,125	1,570,761
14	78,211	431,446	509,657
21	451,164	2,107,962	2,559,126
28	100,364	159,285	259,649
5 July	265,174	1,246,714	1,511,888
12	(435,930)[a]	(1,373,081)	(1,809,011)
19	1,591,166	4,841,898	6,433,064
26	-(b)	-	-
2 August	-	-	-
9	-	-	-
16	315,420	781,457	1,096,877
23	319,549	662,434	981,983
30	831,975	5,000,642	5,832,617
6 September	5,659,216	2,289,299	7,948,515
13	1,311,603	2,032,595	3,344,198
Total	15,917,883	34,381,250	50,299,133

(a) Values in parenthesis were derived using the mean of the density on 26 July and 9 August.
(b) Dash indicates plant not pumping.

TABLE 3-24 WORST CASE ESTIMATES OF MACROINVERTEBRATES ENTRAINED AT THE BRAIDWOOD STATION, 1988

Week Of	Day Drift	Night Drift	Total Drift
19 April	763,833	1,404,228	2,168,061
26	500,927	924,196	1,425,123
3 May	332,423	958,664	1,291,087
10	567,847	1,568,000	2,135,847
17	220,773	2,668,183	2,888,956
24	2,276,358	10,399,123	12,675,481
31	1,043,042	3,132,605	4,175,647
7 June	2,862,895	546,973	3,409,868
14	127,239	688,324	815,563
21	535,507	2,551,857	3,087,364
28	343,546	534,681	878,227
5 July	696,213	3,260,929	3,957,142
12	(2,513,350)(a)	(8,061,571)	(10,574,921)
19	4,277,882	13,074,019	17,351,901
26	-	-	-
2 August	[7,658,889]	[22,713,727]	[30,272,616]
9	-	-	-
16	828,044	2,068,465	2,896,509
23	1,131,242	2,411,556	3,542,798
30	861,693	5,114,179	5,975,872
6 September	5,967,563	2,385,453	8,353,016
13	2,308,978	3,522,148	5,831,126
Total	35,818,244	87,988,881	123,807,125

(a) Values in parenthesis were derived using the mean of the density on 5 July and 19 July.
(b) Values in brackets are estimates for the three week period the plant was decoupled and were derived using densities of 19 July and 16 August.

Horse Creek

An accurate estimate of the Horse Creek macroinvertebrate drift is not possible because in a given week only one day or one night sample was analyzed. If one assumes that the drift during a two-week period can be estimated reliably based on only one day and one night sample, then an estimate of 8 million organisms can be derived. However, this should be considered only a "ballpark" estimate.

Discharge

Data are insufficient to develop an accurate estimate of the number of macroinvertebrates discharged to the river.

3.2 IMPINGEMENT

3.2.1 SPECIES COMPOSITION

The twelve month impingement study at the Braidwood Station resulted in the collection of 59 species of fish (Table 3-25). Two species of special note were pallid shiner and river redhorse. Pallid shiner (chub) is an endangered species and river redhorse is a threatened species as classified by the State of Illinois (Illinois DOC 1989).

A total of 78 fish species has been collected during Kankakee River surveys by the Illinois Natural History Survey (INHS) from 1977 through 1988 (Larimore & Peterson 1989). All species collected during the 1988-1989 impingement study have been previously collected from the river. A comparison of species collected during the 1988-1989 impingement study with those collected during two recent surveys of the river (Table 3-26) shows that five species (goldfish, pirate perch, yellow bass, rainbow darter, and freshwater drum) were unique to the impingement study. Four species (central stoneroller, rudd, starhead topminnow, and walleye) were unique to the river collections. All of the species unique to either the impingement study or the river collections were represented in the catch by 5 or fewer individuals. Sixteen pallid shiners were collected during impingement compared to none in the 1988 river sampling (Larimore and Peterson 1989), and 96 in the 1989 river sampling (Appendix E). The INHS has not collected pallid shiner from the river since 1986 (Larimore and Peterson 1989). River redhorse has been collected by INHS every year from 1977 to 1988. The 1988 INHS river collections yielded nine river redhorse compared to two individuals during the 1988-1989 impingement study.

Raw data from the impingement study are presented in Appendices F and G.

TABLE 3-25 ABUNDANCE OF FISH CAPTURED DURING THE 1988-1989 BRAIDWOOD IMPINGEMENT STUDY

SPECIES	NUMBER TOTAL	NUMBER %	GRAMS TOTAL	GRAMS %
LONGNOSE GAR	2	0.011	4	0.002
GIZZARD SHAD	12,220	69.118	120,831	62.827
GRASS PICKEREL	6	0.034	33	0.017
NORTHERN PIKE	2	0.011	7	0.004
GOLDFISH	1	0.006	125	0.065
COMMON CARP	22	0.124	5,117	2.661
HORNYHEAD CHUB	40	0.226	338	0.176
GOLDEN SHINER	70	0.396	792	0.412
PALLID SHINER	16	0.090	25	0.013
EMERALD SHINER	13	0.074	55	0.029
GHOST SHINER	5	0.028	7	0.004
STRIPED SHINER	97	0.549	999	0.519
RED SHINER	2	0.011	10	0.005
ROSYFACE SHINER	300	1.697	375	0.195
SPOTFIN SHINER	238	1.346	871	0.453
SAND SHINER	20	0.113	40	0.021
REDFIN SHINER	2	0.011	7	0.004
MIMIC SHINER	149	0.843	223	0.116
SPOTFIN X RED SHINER	2	0.011	9	0.005
SUCKERMOUTH MINNOW	5	0.028	22	0.011
BLUNTNOSE MINNOW	170	0.962	738	0.384
FATHEAD MINNOW	51	0.288	125	0.065
BULLHEAD MINNOW	82	0.464	217	0.113
QUILLBACK	27	0.153	2,371	1.233
UNID CARPIODES	2	0.011	8	0.004
WHITE SUCKER	1	0.006	140	0.073
NORTHERN HOG SUCKER	6	0.034	136	0.071
SMALLMOUTH BUFFALO	7	0.040	429	0.223
SPOTTED SUCKER	3	0.017	37	0.019
SILVER REDHORSE	80	0.452	1,447	0.752
RIVER REDHORSE	2	0.011	1,692	0.880
BLACK REDHORSE	2	0.011	192	0.100
GOLDEN REDHORSE	28	0.158	1,572	0.817
SHORTHEAD REDHORSE	119	0.673	2,220	1.154
UNID MOXOSTOMA	6	0.034	10	0.005
BLACK BULLHEAD	17	0.096	246	0.128
YELLOW BULLHEAD	14	0.079	344	0.179
BROWN BULLHEAD	3	0.017	105	0.055
CHANNEL CATFISH	47	0.266	3,437	1.787
STONECAT	90	0.509	2,658	1.382
TADPOLE MADTOM	2	0.011	7	0.004
PIRATE PERCH	1	0.006	6	0.003
BLACKSTRIPE TOPMINNOW	1	0.006	1	0.001
BROOK SILVERSIDE	190	1.075	324	0.168
YELLOW BASS	2	0.011	405	0.211
ROCK BASS	1,816	10.271	16,615	8.639
GREEN SUNFISH	104	0.588	2,447	1.272
ORANGESPOTTED SUNFISH	72	0.407	742	0.386
BLUEGILL	175	0.990	3,079	1.601
LONGEAR SUNFISH	544	3.077	4,056	2.109
HYBRID SUNFISH	2	0.011	19	0.010
UNID LEPOMIS	29	0.164	31	0.016
SMALLMOUTH BASS	553	3.128	8,498	4.419
LARGEMOUTH BASS	43	0.243	2,465	1.282
WHITE CRAPPIE	31	0.175	1,156	0.601
BLACK CRAPPIE	40	0.226	2,680	1.393
RAINBOW DARTER	1	0.006	2	0.001
JOHNNY DARTER	3	0.017	3	0.002
BANDED DARTER	3	0.017	3	0.002
YELLOW PERCH	7	0.040	161	0.084
LOGPERCH	36	0.204	193	0.100
BLACKSIDE DARTER	44	0.249	162	0.084
SLENDERHEAD DARTER	3	0.017	8	0.004
FRESHWATER DRUM	9	0.051	1,246	0.648
TOTAL FISH	17,680	100.000	192,323	100.000

TABLE 3-26 COMPARISON OF FISH SPECIES IN IMPINGEMENT AND RIVER COLLECTIONS FROM THE KANKAKEE RIVER NEAR THE BRAIDWOOD STATION.

Species	Impingement 1988-1989	River Collections[a] 1988	Seine Collections[b] 1989
Longnose gar	X	X	X
Gizzard shad	X	X	X
Grass pickerel	X	X	X
Northern pike	X	-	X
Central stoneroller	-	-	X
Goldfish	X	-	-
Common carp	X	X	X
Hornyhead chub	X	X	X
Rudd	-	X	X
Golden shiner	X	X	X
Pallid shiner[c]	X	-	X
Emerald shiner	X	-	X
Ghost shiner	X	-	X
Striped shiner	X	X	X
Red shiner	X	-	X
Rosyface shiner	X	X	X
Spotfin shiner	X	X	X
Sand shiner	X	X	X
Redfin shiner	X	X	X
Mimic shiner	X	X	X
Spotfin x Red shiner	X	-	-
Suckermouth minnow	X	X	-
Bluntnose minnow	X	X	X
Fathead minnow	X	-	X
Bullhead minnow	X	X	X
Quillback	X	X	X
White sucker	X	X	X
Northern Hogsucker	X	X	X
Smallmouth buffalo	X	X	X
Spotted sucker	X	-	X
Silver redhorse	X	X	X
River redhorse[d]	X	X	X
Black redhorse	X	X	X
Golden redhorse	X	X	X
Shorthead redhorse	X	X	X
Black bullhead	X	-	X
Yellow bullhead	X	X	X
Brown bullhead	X	-	X
Channel catfish	X	X	X
Stonecat	X	X	-
Tadpole madtom	X	-	X
Pirate perch	X	-	-
Blackstripe topminnow	X	X	X
Starhead topminnow	-	-	X
Brook silverside	X	X	X
Yellow bass	X	-	-
Rock bass	X	X	X
Green sunfish	X	X	X

TABLE 3-26(CONT.)

Species	Impingement 1988-1989	River Collections[a] 1988	Seine Collections[b] 1989
Orangespotted sunfish	X	X	X
Bluegill	X	X	X
Longear sunfish	X	X	X
Hybrid sunfish	X	-	-
Smallmouth bass	X	X	X
Largemouth bass	X	X	X
White crappie	X	-	X
Black crappie	X	X	X
Rainbow darter	X	-	-
Johnny darter	X	X	X
Banded darter	X	X	X
Yellow perch	X	X	X
Logperch	X	X	X
Blackside darter	X	X	X
Slenderhead darter	X	X	X
Walleye	-	X	X
Freshwater drum	X	-	-
Total Species	59	45	56

(a) Larimore and Peterson 1989.
(b) EA 1989.
(c) State of Illinois Endangered species
(d) State of Illinois Threatened species.

3.2.2 RELATIVE ABUNDANCE

A total of 17,680 fish was collected in the 1988-1989 impingement study at the Braidwood Station (Table 3-25). Gizzard shad strongly dominated the collections (12,220 individuals; 69.1 percent of the total impingement). Other species which comprised greater than 1 percent of the total catch included: rock bass (1,816; 10.3), smallmouth bass (553; 3.1), longear sunfish (544; 3.1), rosyface shiner (300; 1.7), spotfin shiner (238; 1.3), and brook silverside (190; 1.1). Gizzard shad also dominated the catch in terms of biomass (62.8 percent), followed by rock bass (8.7), smallmouth bass (4.4), carp (2.2), and longear sunfish (2.1). No other species accounted for more than 2 percent of the biomass (Table 3-25).

3.2.3 TEMPORAL VARIATION

Considerable temporal fluctuations were noted in monthly and daily catches, particularly during the period from October (1988) through March (1989) (Figure 3-7); the highest monthly catch occurred during this six month period. Monthly catches during this period ranged from 1,108 in February to 6,310 in December. Catch rates (number impinged/hour) ranged from 4.2 fish per hour in February to 26.1 in December:

	Oct	Nov	Dec	Jan	Feb	Mar
Total Catch	1,265	1,863	6,310	3,942	1,108	1,981
No. Fish/Hour	5.8	5.9	26.1	15.7	4.2	7.5
No. of Species	15	32	30	45	36	47

Ninety-three percent of the entire catch occurred during this six month period. Species richness was highest in March (47 species) and January (45 species) and averaged 34 species during the first six months of the study.

Impingement catch rates decreased dramatically during the last six months (April-September) of the study. Since fewer than 100 hours were sampled in September (because pumping often could not occur because the cooling lake was full) and only three collections were made in October 1989, comparisons will emphasize the April through August period. Total catches during this 5-month period ranged from a low of 85 in August to a high of 457 in May. Catch rates were highest in April (1.8 fish per hour) and lowest in August (0.3 fish per hour):

	Apr	May	Jun	Jul	Aug
Total Catch	269	457	180	176	85
No. Fish/Hour	1.8	1.3	0.6	0.9	0.3
No. of Species	33	33	38	22	26

Species richness during the spring/summer period ranged from 22 species (July) to 38 species (June). A comparison of mean monthly total catches, catch rates, and species richness (i.e., No. of Species), for October - March vs. April - August is as follows:

	Monthly Means		
	Total Catch	Catch/Hour	Species Richness
October - March	2,745	10.9	34
April - August	233	1.0	30

During October-March, monthly total catches and catch rates were approximately 10 times higher than during April - August. Species richness was similar between the two periods.

As previously mentioned, considerable fluctuations were noted in monthly and daily catches from October through March (Figure 3-7). The fluctuations from October through January were due solely to gizzard shad (Figure 3-8), as they accounted for 84 percent of the daily catch during this period (Appendix G). The relative abundance of gizzard shad and the next three most common species is summarized below:

	Gizzard Shad	Rock bass	Smallmouth bass	Longear sunfish	All Others
Oct	90.9	3.4	1.9	1.2	2.6
Nov	72.9	10.4	1.6	2.8	12.3
Dec	95.2	2.4	0.3	0.4	1.7
Jan	78.8	7.8	3.2	1.5	8.7
Feb	44.0	16.7	7.4	4.4	27.5

Gizzard shad was the dominant species from October through February. Rock bass was consistently the second most abundant species impinged, while smallmouth bass and longear sunfish were typically the third or fourth most abundant taxa collected. Young-of-the-year Lepomis were common in November and rosyface shiner was common in February.

The relative abundance of gizzard shad decreased dramatically in March, as it comprised only 1.2 percent of the March catch. Rock bass was the dominant species in March, April,

FIGURE 3-7.

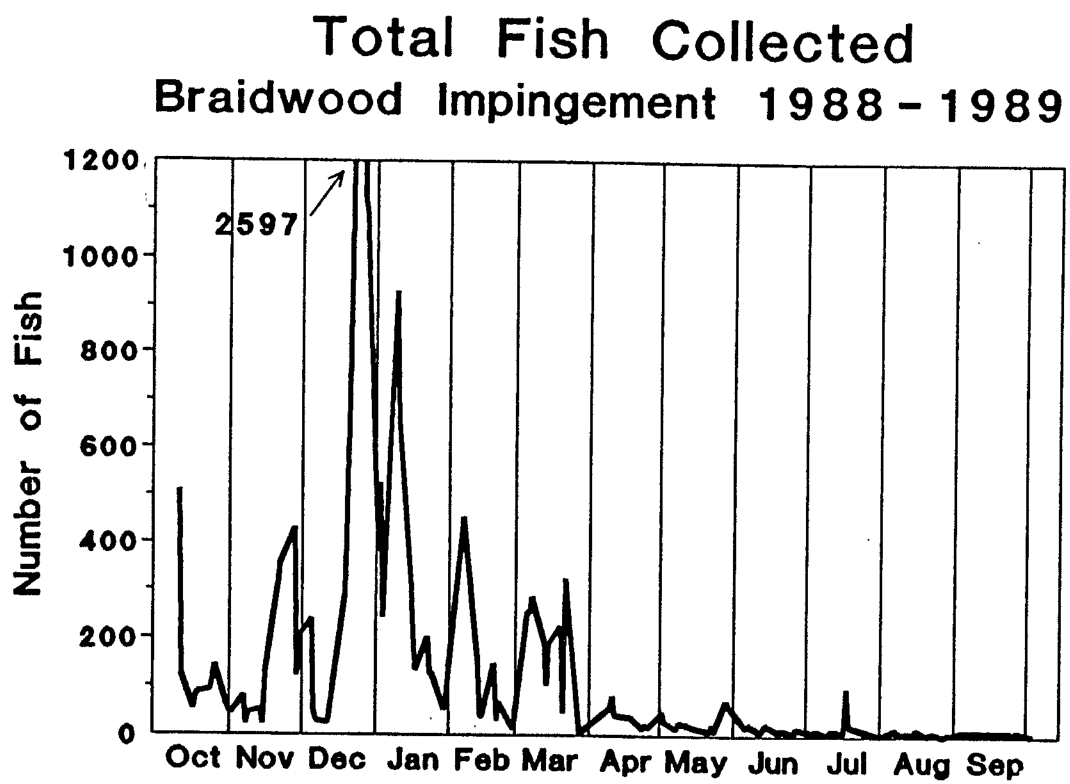
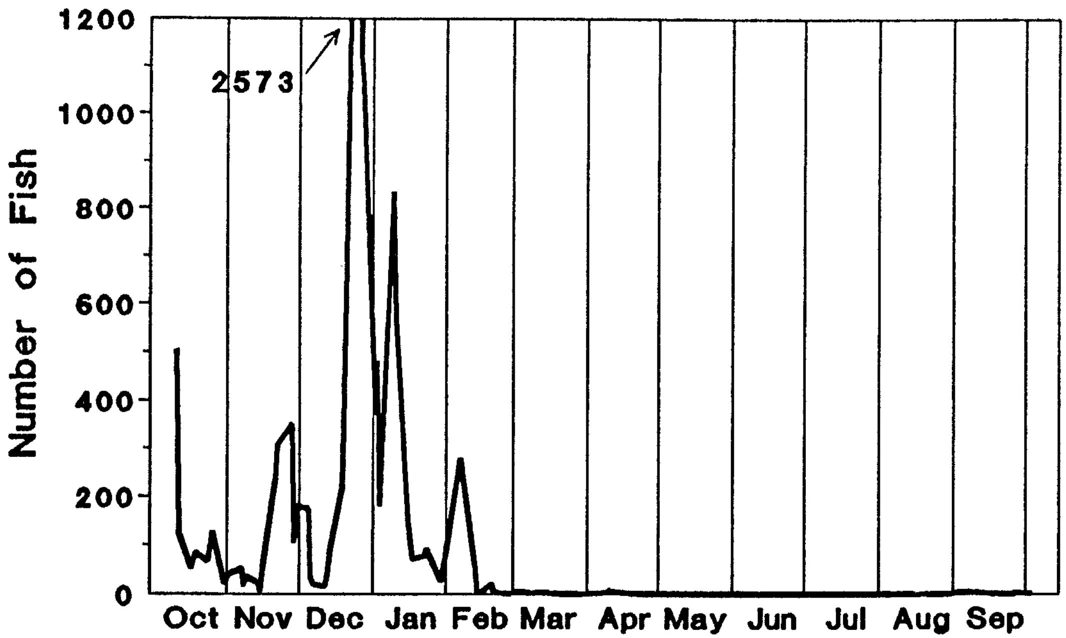

Total Fish Collected
Braidwood Impingement 1988 - 1989
Number of Fish
1200
1000
800
600
400
200
0
2597
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep

FIGURE 3-8.

Gizzard Shad Collected
Braidwood Impingement 1988 - 1989



and May comprising 40.6, 23.8, and 11.9 percent of the monthly catches, respectively. Striped shiner, spotfin shiner, and mimic shiner were the three most abundant species collected in June. The July catch was dominated by longear sunfish (43 percent), whereas rock bass was the most commonly collected species in August and September/October when it accounted for one-quarter of the catch (Appendix G).

The endangered pallid shiner was collected on 11 of 21 sampling dates from 19 April through 6 June. Single specimens of the threatened river redhorse were collected on 3 January and 6 June 1989 (Appendix F).

3.2.4 LENGTH DISTRIBUTION OF SELECTED FISH SPECIES

Length frequency figures were developed for common species to document which size classes of fish were most commonly collected in the impingement samples. Length data was compiled for the seven most common species (excluding minnows) collected during the 1988-1989 study. These seven species (gizzard shad, rock bass, smallmouth bass, longear sunfish, bluegill, shorthead redhorse, and silver redhorse) comprised 88 percent of the total number of fish collected during impingement sampling (Table 3-25).

Gizzard shad impinged during the 1988-1989 study ranged from 22 to 403 mm and averaged 108.4 mm in length (Figure 3-9). The large majority of the gizzard shad collected (86 percent) were between 55 and 135 mm long indicating that most of the gizzard shad collected were young-of-the-year (YOY) specimens. Length-frequency distributions for gizzard shad collected during the 1988 river collections also showed domination by YOY fish (40-120 mm). Very successful gizzard shad spawns were observed in the river in 1987 and 1988 (Dickson 1988; Larimore and Peterson 1989).

Rock bass impinged during the 1988-1989 study ranged from 30 to 261 mm and averaged 70.6 mm in length (Figure 3-10). Eighty-five percent of the rock bass collected were 45 to 85 mm long, indicating the predominance of YOY fish. Rock bass collected during the 1988 river survey were also dominated by YOY fish (20-60 mm) (Larimore and Peterson, 1989).

Smallmouth bass ranged from 57 to 375 mm and averaged 97.3 mm (Figure 3-11). Nearly 90 percent of impinged smallmouth bass were YOYs between 65 and 125 mm in total length. This is similar to the 1988 INHS smallmouth bass catch where YOYs (40-100 mm) comprised 91.0 percent of the total catch (Larimore and Peterson 1989).

Longear sunfish ranged in length from 28 to 133 mm and averaged 60.1 mm in length (Figure 3-12). Fifty-two percent of the total catch of longear sunfish occurred in a narrow length interval from 35 to 55 mm, obviously YOY fish. Longear sunfish were nearly evenly distributed among other length intervals up to 125 mm (Figure 3-12). This obfuscation may

FIGURE 3-9.

1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

--- SPECIES CODE=GIZZARD SHAD ---

PERCENTAGE OF LENGTH

LENGTH MIDPOINT	TOTAL LENGTH (mm)	FREQ	CUM FREQ	PERCENT	CUM PERCENT
10		0	0	0.00	0.00
20		1	1	0.07	0.07
30		0	1	0.00	0.07
40	*	5	6	0.33	0.40
50	***	22	28	1.46	1.86
60	*************	95	123	6.31	8.17
70	***********************	175	298	11.62	19.79
80	******************	139	437	9.23	29.02
90	****************	123	560	8.17	37.18
100	*************************	185	745	12.28	49.47
110	***********************************	262	1007	17.40	66.87
120	**************************	193	1200	12.82	79.68
130	*****************	126	1326	8.37	88.05
140	*********	68	1394	4.52	92.56
150	*****	36	1430	2.39	94.95
160	**	13	1443	0.86	95.82
170	*	5	1448	0.33	96.15
180	*	7	1455	0.46	96.61
190		3	1458	0.20	96.81
200		3	1461	0.20	97.01
210		3	1464	0.20	97.21
220		1	1465	0.07	97.28
230		1	1466	0.07	97.34
240		2	1468	0.13	97.48
250		0	1468	0.00	97.48
260		1	1469	0.07	97.54
270		2	1471	0.13	97.68
280		0	1471	0.00	97.68
290		2	1473	0.13	97.81
300	*	4	1477	0.27	98.07
310		3	1480	0.20	98.27
320	*	8	1488	0.53	98.80
330	*	4	1492	0.27	99.07
340	*	5	1497	0.33	99.40
350		2	1499	0.13	99.54
360		3	1502	0.20	99.73
370		3	1505	0.20	99.93
380		0	1505	0.00	99.93
390		0	1505	0.00	99.93
400		1	1506	0.07	100.00
410		0	1506	0.00	100.00
420		0	1506	0.00	100.00
430		0	1506	0.00	100.00
440		0	1506	0.00	100.00
450		0	1506	0.00	100.00
460		0	1506	0.00	100.00
470		0	1506	0.00	100.00
480		0	1506	0.00	100.00
490		0	1506	0.00	100.00
500		0	1506	0.00	100.00

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

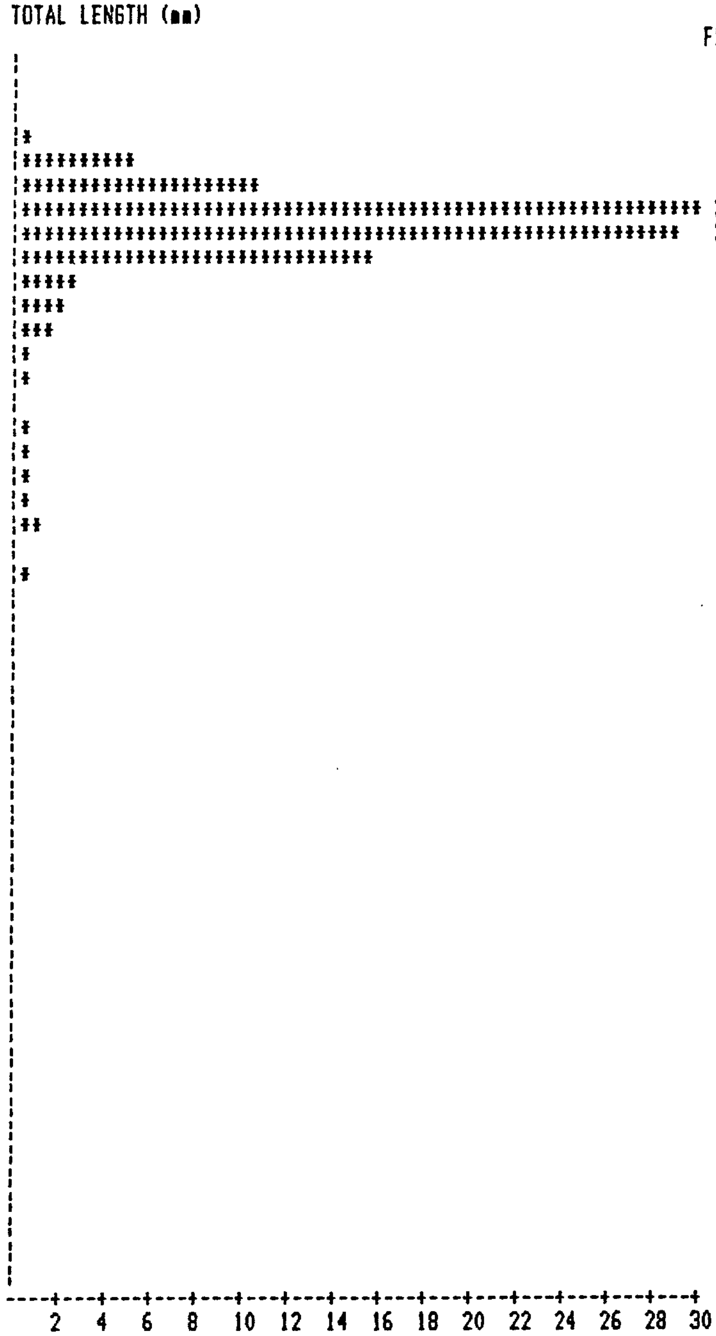
PERCENTAGE

FIGURE 3-10.

1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

-- SPECIES CODE=ROCK BASS --

PERCENTAGE OF LENGTH



LENGTH MIDPOINT	FREQ	CUM FREQ	PERCENT	CUM PERCENT
10	1	1	0.09	0.09
20	0	1	0.00	0.09
30	3	4	0.26	0.34
40	60	64	5.15	5.50
50	123	187	10.57	16.07
60	348	535	29.90	45.96
70	337	872	28.95	74.91
80	181	1053	15.55	90.46
90	30	1083	2.58	93.04
100	24	1107	2.06	95.10
110	17	1124	1.46	96.56
120	4	1128	0.34	96.91
130	3	1131	0.26	97.16
140	2	1133	0.17	97.34
150	4	1137	0.34	97.68
160	3	1140	0.26	97.94
170	3	1143	0.26	98.20
180	5	1148	0.43	98.63
190	9	1157	0.77	99.40
200	2	1159	0.17	99.57
210	4	1163	0.34	99.91
220	0	1163	0.00	99.91
230	0	1163	0.00	99.91
240	0	1163	0.00	99.91
250	0	1163	0.00	99.91
260	1	1164	0.09	100.00
270	0	1164	0.00	100.00
280	0	1164	0.00	100.00
290	0	1164	0.00	100.00
300	0	1164	0.00	100.00
310	0	1164	0.00	100.00
320	0	1164	0.00	100.00
330	0	1164	0.00	100.00
340	0	1164	0.00	100.00
350	0	1164	0.00	100.00
360	0	1164	0.00	100.00
370	0	1164	0.00	100.00
380	0	1164	0.00	100.00
390	0	1164	0.00	100.00
400	0	1164	0.00	100.00
410	0	1164	0.00	100.00
420	0	1164	0.00	100.00
430	0	1164	0.00	100.00
440	0	1164	0.00	100.00
450	0	1164	0.00	100.00
460	0	1164	0.00	100.00
470	0	1164	0.00	100.00
480	0	1164	0.00	100.00
490	0	1164	0.00	100.00
500	0	1164	0.00	100.00

FIGURE 3-11.
1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

-- SPECIES CODE=SMALLMOUTH BASS --

PERCENTAGE OF LENGTH

LENGTH MIDPOINT	TOTAL LENGTH (mm) FREQ	CUM FREQ	PERCENT	CUM PERCENT
10	0	0	0.00	0.00
20	0	0	0.00	0.00
30	0	0	0.00	0.00
40	0	0	0.00	0.00
50	0	0	0.00	0.00
60	15	15	2.86	2.86
70	47	62	8.97	11.83
80	110	172	20.99	32.82
90	126	298	24.05	56.87
100	94	392	17.94	74.81
110	64	456	12.21	87.02
120	30	486	5.73	92.75
130	12	498	2.29	95.04
140	9	507	1.72	96.76
150	7	514	1.34	98.09
160	2	516	0.38	98.47
170	1	517	0.19	98.66
180	2	519	0.38	99.05
190	0	519	0.00	99.05
200	0	519	0.00	99.05
210	0	519	0.00	99.05
220	0	519	0.00	99.05
230	1	520	0.19	99.24
240	0	520	0.00	99.24
250	0	520	0.00	99.24
260	0	520	0.00	99.24
270	0	520	0.00	99.24
280	0	520	0.00	99.24
290	1	521	0.19	99.43
300	1	522	0.19	99.62
310	0	522	0.00	99.62
320	1	523	0.19	99.81
330	0	523	0.00	99.81
340	0	523	0.00	99.81
350	0	523	0.00	99.81
360	0	523	0.00	99.81
370	1	524	0.19	100.00
380	0	524	0.00	100.00
390	0	524	0.00	100.00
400	0	524	0.00	100.00
410	0	524	0.00	100.00
420	0	524	0.00	100.00
430	0	524	0.00	100.00
440	0	524	0.00	100.00
450	0	524	0.00	100.00
460	0	524	0.00	100.00
470	0	524	0.00	100.00
480	0	524	0.00	100.00
490	0	524	0.00	100.00
500	0	524	0.00	100.00

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

PERCENTAGE

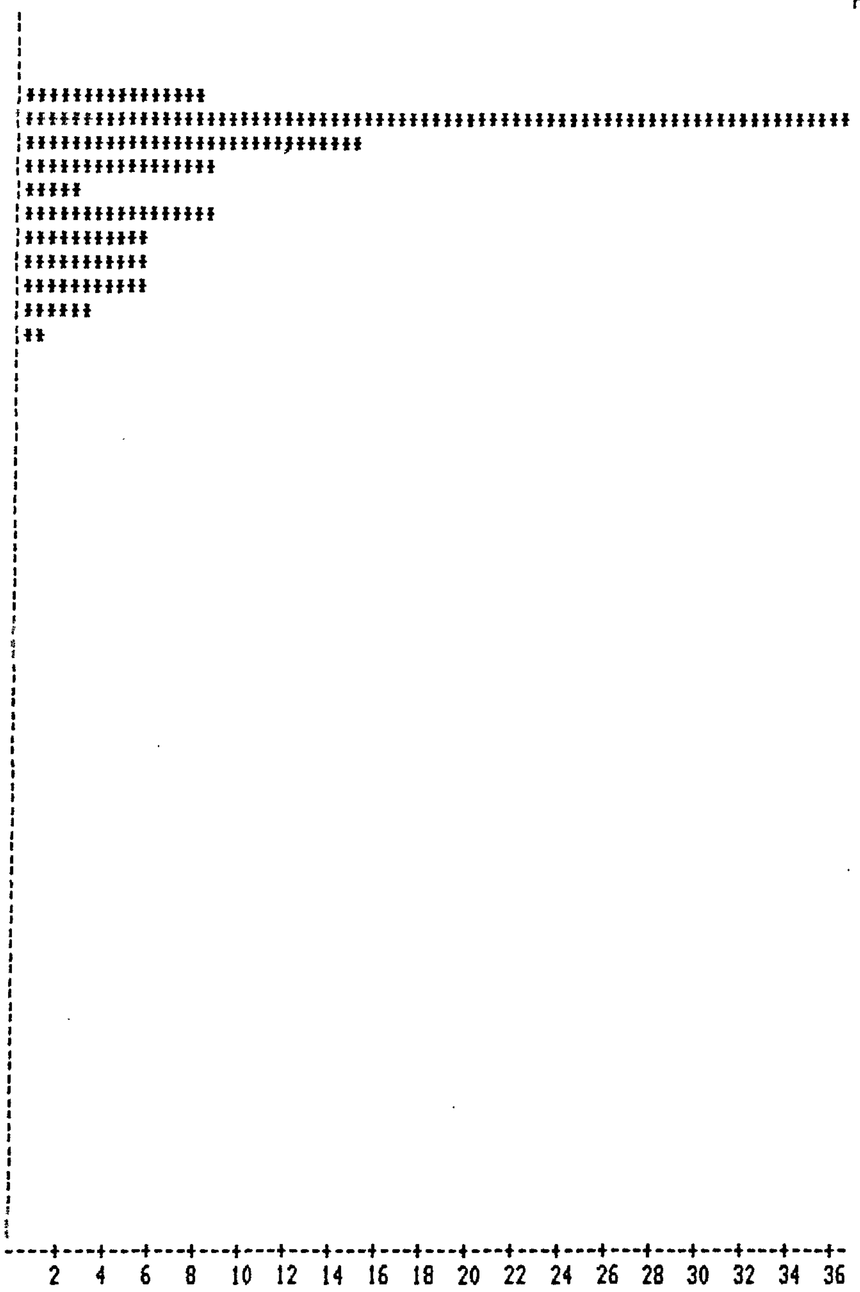
FIGURE 3-12.

1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

SPECIES CODE=LONGEAR SUNFISH

PERCENTAGE OF LENGTH

TOTAL LENGTH (mm)



PERCENTAGE

LENGTH MIDPOINT	FREQ	CUM FREQ	PERCENT	CUM PERCENT
10	0	0	0.00	0.00
20	0	0	0.00	0.00
30	40	40	8.10	8.10
40	181	221	36.64	44.74
50	75	296	15.18	59.92
60	43	339	8.70	68.62
70	12	351	2.43	71.05
80	43	394	8.70	79.76
90	28	422	5.67	85.43
100	27	449	5.47	90.89
110	26	475	5.26	96.15
120	14	489	2.83	98.99
130	5	494	1.01	100.00
140	0	494	0.00	100.00
150	0	494	0.00	100.00
160	0	494	0.00	100.00
170	0	494	0.00	100.00
180	0	494	0.00	100.00
190	0	494	0.00	100.00
200	0	494	0.00	100.00
210	0	494	0.00	100.00
220	0	494	0.00	100.00
230	0	494	0.00	100.00
240	0	494	0.00	100.00
250	0	494	0.00	100.00
260	0	494	0.00	100.00
270	0	494	0.00	100.00
280	0	494	0.00	100.00
290	0	494	0.00	100.00
300	0	494	0.00	100.00
310	0	494	0.00	100.00
320	0	494	0.00	100.00
330	0	494	0.00	100.00
340	0	494	0.00	100.00
350	0	494	0.00	100.00
360	0	494	0.00	100.00
370	0	494	0.00	100.00
380	0	494	0.00	100.00
390	0	494	0.00	100.00
400	0	494	0.00	100.00
410	0	494	0.00	100.00
420	0	494	0.00	100.00
430	0	494	0.00	100.00
440	0	494	0.00	100.00
450	0	494	0.00	100.00
460	0	494	0.00	100.00
470	0	494	0.00	100.00
480	0	494	0.00	100.00
490	0	494	0.00	100.00
500	0	494	0.00	100.00

be attributed to sexual dimorphism in size at maturity and, in turn, growth rates (Scott and Crossman 1973).

Impinged bluegills ranged in length from 25 to 182 mm and averaged 72.5 mm (Figure 3-13). Fifty-nine percent of the impinged bluegills were YOYs between 35 and 65 mm. Bluegill was the only species in which adults (>130 mm) were fairly common (15.4 percent) in impingement collections.

Silver and shorthead redhorse greater than 140 mm were almost nonexistent in the impingement collections (Figures 3-14 and 3-15). Nearly identical percentages of these two species occurred in the 95 to 125 mm length interval, 68.8 percent for silver redhorse and 65.6 percent for shorthead redhorse. Impinged silver redhorse ranged in length from 81 to 217 mm and averaged 110.5 mm in length. Shorthead redhorse ranged in length from 35 to 379 mm and averaged 107.7 mm in length.

3.2.5 IMPINGEMENT ESTIMATES

The twelve month impingement estimate for the 1988-1989 sampling period at Braidwood Station was 53,111 fish (Table 3-27). Of this total, gizzard shad was clearly the dominant species, comprising 68.9 percent (36,608 individuals) of the annual estimate. Rock bass (5129 individuals) accounted for 9.7 percent of the annual estimate, while smallmouth bass (1594 individuals) accounted for 3.0 percent of the estimate.

Fifty-one percent (26,870 individuals) of the annual estimate occurred during a four-week period from the week of 18 December through the week of 8 January. Of the 26,870 fish estimated during this period, 25,062 (93.3 percent) were gizzard shad (Table 3-27).

The number of pallid shiners impinged was estimated because it is an endangered species. The annual estimate was 73, all of which occurred from mid-April to early June.

3.2.6 PHYSICAL/CHEMICAL MEASUREMENTS

Water temperatures measured at the Intake during the impingement study ranged from 0.0 to 31.2 C (Table 3-28). Temperatures typically showed little or no vertical variation from surface to bottom (Appendix H). Mean monthly temperatures were highest in July (25.0 C) and lowest in February (0.4 C). The greatest temperature variations occurred during April, when temperatures varied by 10.1 C over the course of the month.

Dissolved oxygen (DO) concentrations ranged between 5.9 to 17.0 mg/l during the study (Table 3-28). DO concentrations, like temperature, were typically homogeneously distributed throughout the water column (Appendix H). The highest monthly mean DO

FIGURE 3-13.

1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

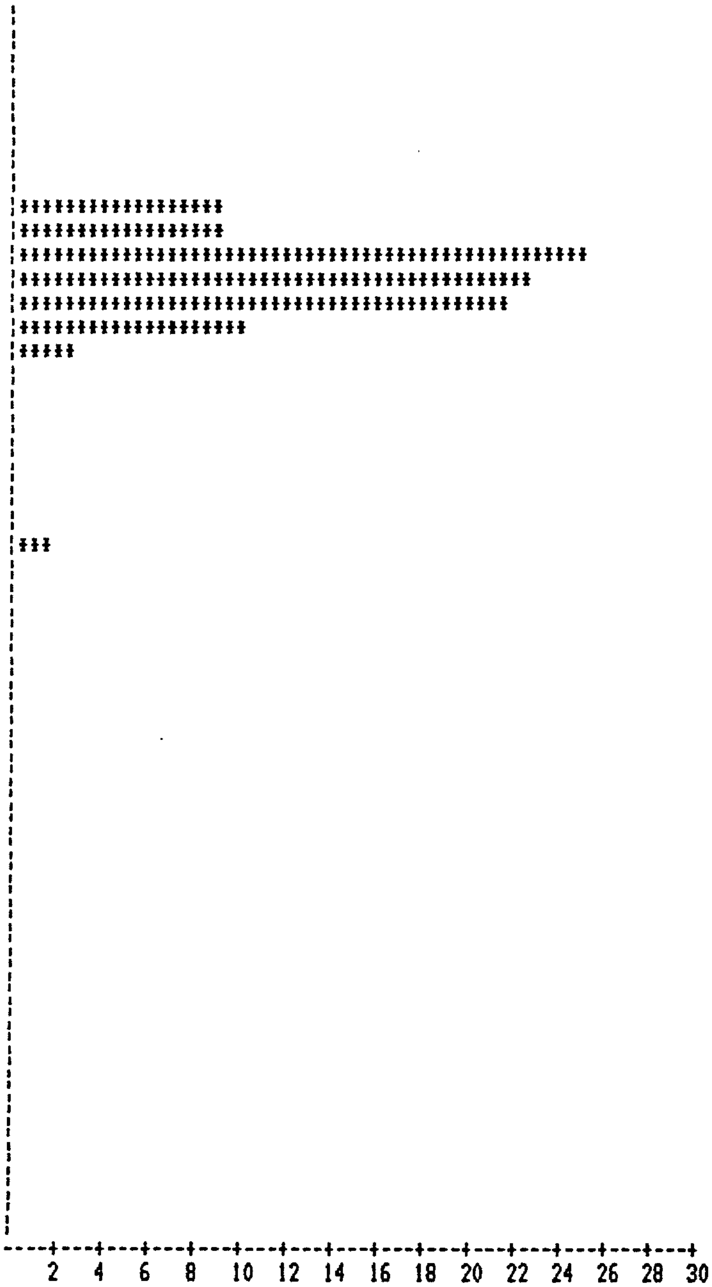
```
------------------------------------------------ SPECIES CODE=BLUEGILL ------------------------------------------------

PERCENTAGE OF LENGTH

LENGTH   TOTAL LENGTH (mm)                                                      CUM                CUM
MIDPOINT                                                                 FREQ   FREQ   PERCENT   PERCENT
         |
   10    |                                                                  0      0      0.00      0.00
   20    |*                                                                 1      1      0.57      0.57
   30    |*************                                                    11     12      6.29      6.86
   40    |*****************************                                    25     37     14.29     21.14
   50    |**************************************************               44     81     25.14     46.29
   60    |****************************************                         35    116     20.00     66.29
   70    |***********                                                      10    126      5.71     72.00
   80    |**********                                                        9    135      5.14     77.14
   90    |*********                                                         8    143      4.57     81.71
  100    |**                                                                2    145      1.14     82.86
  110    |***                                                               3    148      1.71     84.57
  120    |                                                                  0    148      0.00     84.57
  130    |*****                                                             4    152      2.29     86.86
  140    |**                                                                2    154      1.14     88.00
  150    |********                                                          7    161      4.00     92.00
  160    |*********                                                         8    169      4.57     96.57
  170    |**                                                                2    171      1.14     97.71
  180    |*****                                                             4    175      2.29    100.00
  190    |                                                                  0    175      0.00    100.00
  200    |                                                                  0    175      0.00    100.00
  210    |                                                                  0    175      0.00    100.00
  220    |                                                                  0    175      0.00    100.00
  230    |                                                                  0    175      0.00    100.00
  240    |                                                                  0    175      0.00    100.00
  250    |                                                                  0    175      0.00    100.00
  260    |                                                                  0    175      0.00    100.00
  270    |                                                                  0    175      0.00    100.00
  280    |                                                                  0    175      0.00    100.00
  290    |                                                                  0    175      0.00    100.00
  300    |                                                                  0    175      0.00    100.00
  310    |                                                                  0    175      0.00    100.00
  320    |                                                                  0    175      0.00    100.00
  330    |                                                                  0    175      0.00    100.00
  340    |                                                                  0    175      0.00    100.00
  350    |                                                                  0    175      0.00    100.00
  360    |                                                                  0    175      0.00    100.00
  370    |                                                                  0    175      0.00    100.00
  380    |                                                                  0    175      0.00    100.00
  390    |                                                                  0    175      0.00    100.00
  400    |                                                                  0    175      0.00    100.00
  410    |                                                                  0    175      0.00    100.00
  420    |                                                                  0    175      0.00    100.00
  430    |                                                                  0    175      0.00    100.00
  440    |                                                                  0    175      0.00    100.00
  450    |                                                                  0    175      0.00    100.00
  460    |                                                                  0    175      0.00    100.00
  470    |                                                                  0    175      0.00    100.00
  480    |                                                                  0    175      0.00    100.00
  490    |                                                                  0    175      0.00    100.00
  500    |                                                                  0    175      0.00    100.00
         ----+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
             2   4   6   8  10  12  14  16  18  20  22  24  26  28  30

                              PERCENTAGE
```

FIGURE 3-14.
1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

--- SPECIES CODE=SILVER REDHORSE ---

PERCENTAGE OF LENGTH

LENGTH MIDPOINT — TOTAL LENGTH (mm)



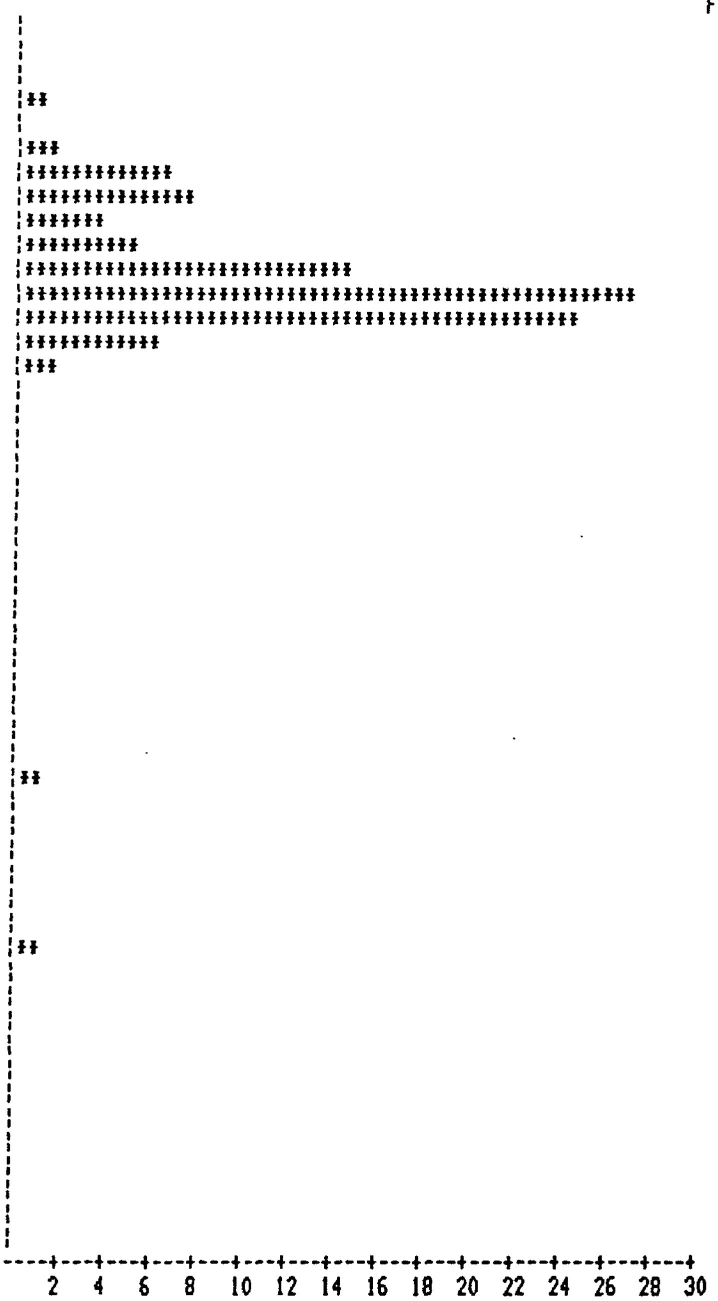
LENGTH MIDPOINT	FREQ	CUM FREQ	PERCENT	CUM PERCENT
10	0	0	0.00	0.00
20	0	0	0.00	0.00
30	0	0	0.00	0.00
40	0	0	0.00	0.00
50	0	0	0.00	0.00
60	0	0	0.00	0.00
70	0	0	0.00	0.00
80	7	7	8.75	8.75
90	7	14	8.75	17.50
100	20	34	25.00	42.50
110	18	52	22.50	65.00
120	17	69	21.25	86.25
130	8	77	10.00	96.25
140	2	79	2.50	98.75
150	0	79	0.00	98.75
160	0	79	0.00	98.75
170	0	79	0.00	98.75
180	0	79	0.00	98.75
190	0	79	0.00	98.75
200	0	79	0.00	98.75
210	0	79	0.00	98.75
220	1	80	1.25	100.00
230	0	80	0.00	100.00
240	0	80	0.00	100.00
250	0	80	0.00	100.00
260	0	80	0.00	100.00
270	0	80	0.00	100.00
280	0	80	0.00	100.00
290	0	80	0.00	100.00
300	0	80	0.00	100.00
310	0	80	0.00	100.00
320	0	80	0.00	100.00
330	0	80	0.00	100.00
340	0	80	0.00	100.00
350	0	80	0.00	100.00
360	0	80	0.00	100.00
370	0	80	0.00	100.00
380	0	80	0.00	100.00
390	0	80	0.00	100.00
400	0	80	0.00	100.00
410	0	80	0.00	100.00
420	0	80	0.00	100.00
430	0	80	0.00	100.00
440	0	80	0.00	100.00
450	0	80	0.00	100.00
460	0	80	0.00	100.00
470	0	80	0.00	100.00
480	0	80	0.00	100.00
490	0	80	0.00	100.00
500	0	80	0.00	100.00

FIGURE 3-15.

1988-89 BRAIDWOOD STATION IMPINGEMENT STUDY - LENGTH FREQUENCIES

--- SPECIES CODE=SHORTHEAD REDHORSE ---

PERCENTAGE OF LENGTH



LENGTH MIDPOINT	FREQ	CUM FREQ	PERCENT	CUM PERCENT
10	0	0	0.00	0.00
20	0	0	0.00	0.00
30	1	1	0.84	0.84
40	0	1	0.00	0.84
50	2	3	1.68	2.52
60	8	11	6.72	9.24
70	9	20	7.56	16.81
80	4	24	3.36	20.17
90	6	30	5.04	25.21
100	17	47	14.29	39.50
110	32	79	26.89	66.39
120	29	108	24.37	90.76
130	7	115	5.88	96.64
140	2	117	1.68	98.32
150	0	117	0.00	98.32
160	0	117	0.00	98.32
170	0	117	0.00	98.32
180	0	117	0.00	98.32
190	0	117	0.00	98.32
200	0	117	0.00	98.32
210	0	117	0.00	98.32
220	0	117	0.00	98.32
230	0	117	0.00	98.32
240	0	117	0.00	98.32
250	0	117	0.00	98.32
260	0	117	0.00	98.32
270	0	117	0.00	98.32
280	0	117	0.00	98.32
290	0	117	0.00	98.32
300	0	117	0.00	98.32
310	1	118	0.84	99.16
320	0	118	0.00	99.16
330	0	118	0.00	99.16
340	0	118	0.00	99.16
350	0	118	0.00	99.16
360	0	118	0.00	99.16
370	0	118	0.00	99.16
380	1	119	0.84	100.00
390	0	119	0.00	100.00
400	0	119	0.00	100.00
410	0	119	0.00	100.00
420	0	119	0.00	100.00
430	0	119	0.00	100.00
440	0	119	0.00	100.00
450	0	119	0.00	100.00
460	0	119	0.00	100.00
470	0	119	0.00	100.00
480	0	119	0.00	100.00
490	0	119	0.00	100.00
500	0	119	0.00	100.00

TABLE 3-27. WEEKLY ESTIMATED IMPINGEMENT OF SELECTED SPECIES AND TOTAL CATCH AT THE BRAIDWOOD STATION, 1988-1989

Week of	Gizzard shad	Rock bass	Smallmouth bass	Total
9 October	2,225	4	7	2,246
16	478	2	12	508
23	679	35	37	813
30	223	88	7	355
6 November	243	51	0	348
13	193	68	27	461
20	1,867	152	21	2,300
27	1,496	146	14	1,774
4 December	531	96	14	739
11	312	50	7	419
18	3,081	200	10	3,425
25	11,148	59	2	11,284
1 January	5,746	384	100	6,403
8	5,087	156	156	5,758
15	755	189	78	1,426
22	577	204	65	1,054
29	503	112	50	837
5 February	986	176	85	1,599
12	168	133	54	548
19	63	133	51	573
26	12	38	38	182
5 March	19	902	283	1,919
12	22	361	102	1,181
19	5	599	61	1,386
26	0	152	59	386
2 April	(17) *	(134)	(35)	(402)
9	35	117	12	418
16	70	105	35	1,330
23	5	26	16	122
30	0	49	12	277
7 May	0	5	5	151
14	2	14	7	107
21	2	10	15	102
28	0	61	46	571
4 June	2	5	15	151
11	2	16	0	107
18	2	7	0	82
25	0	0	0	87
2 July	0	4	7	74
9	0	7	5	54
16	0	40	18	396
23	(0)	(21)	10	(207)
30	0	2	2	19
6 August	2	5	5	73
13	0	9	5	60
20	5	0	0	35
27	5	2	0	19

TABLE 3-27(CONT.)

Week of	Gizzard shad	Rock bass	Smallmouth bass	Total
3 September	10	0	0	108
10	(10)	(0)	(0)	(108)
17	(9)	(0)	(2)	(51)
24	9	0	2	51
1 October	2	0	0	25
Total	36,608	5,129	1,594	53,111
Percent of Total Catch	68.9	9.7	3.0	

* Values in parenthesis were based on rates from the preceding and following weeks

TABLE 3-28. SUMMARY OF SURFACE TEMPERATURE AND DISSOLVED OXYGEN MEASUREMENTS COLLECTED DURING IMPINGEMENT SAMPLING AT THE BRAIDWOOD STATION, 1988-1989

Month	Temperature (C)		Dissolved Oxygen (mg/l)	
	Mean	Range	Mean	Range
Oct 1988	9.7	7.0-14.0	12.3	11.1-13.8
Nov 1988	6.3	3.2- 9.0	14.4	12.0-16.2
Dec 1988	1.4	0.0- 3.4	14.6	12.6-17.0
Jan 1989	1.6	0.0- 5.5	12.5	10.8-14.7
Feb 1989	0.4	0.0- 4.0	13.0	11.8-13.8
Mar 1989	2.1	0.0- 6.5	13.1	11.2-14.4
Apr 1989	11.5	7.0-17.1	10.4	7.4-13.4
May 1989	17.1	12.8-20.4	8.7	7.9- 9.6
Jun 1989	21.3	19.0-25.4	7.5	6.1- 9.3
Jul 1989	25.0	19.2-31.2	6.8	5.9- 8.5
Aug 1989	24.7	23.2-26.6	7.6	6.2- 9.2
Sep 1989	15.3	13.4-20.0	8.5	7.2- 9.1
Oct 1989	13.5	12.9-14.5	8.9	7.7- 9.5

value occurred in December (14.6 mg/l) with the lowest monthly mean value being measured in July (6.8 mg/l). The greatest DO differential occurred during April when DO values varied by 6.3 mg/l over the course of the month.

Intake velocities were measured on 13 April and 1 June (Table 3-29). The river flow on 13 April was 7,060 cfs. On this date, the mean velocity was 0.34 ft/sec in the upstream bay and 0.39 ft/sec in the downstream bay. Intake velocities on 13 April were highest at the surface. River flow data for 1 June are not presently available from USGS. On this date, the mean velocity in the upstream bay was 0.29 ft/sec compared to 0.32 ft/sec in the downstream bay. Intake velocities on 1 June were highest at 2 meters. (Table 3-29).

TABLE 3-29 CURRENT VELOCITIES AT THE INTAKE OF THE BRAIDWOOD STATION ON THE KANKAKEE RIVER.

Date	River Flow (cfs)	Intake Flow (cfs)	Depth (m)	Velocity (ft/sec)							
				Upstream Bay				Downstream Bay			
13 April 1989	7,060	104	SUR	0.47	0.70	0.55	0.49	0.70	0.58	0.48	0.20
			1.0	0.21	0.60	0.63	0.58	0.55	0.82	0.35	0.15
			2.0	0.00	0.09	0.54	0.45	0.32	0.72	0.18	0.00
			2.7	0.00	0.00	0.12	0.07	0.38	0.59	0.00	0.20
1 June 1989	*	107	SUR	0.40	0.20	0.20	0.15	0.10	0.20	0.05	0.00
			1.0	0.50	0.30	0.40	0.00	0.20	0.65	0.50	0.00
			2.0	0.80	0.45	0.45	0.10	0.50	0.97	0.15	0.15
			3.0	0.25	0.20	0.10	0.10	0.90	0.75	0.00	0.00

* Data not available from USGS.

4. DISCUSSION

4.1 ICHTHYOPLANKTON DRIFT

4.1.1 Kankakee River

Previous ichthyoplankton studies in the Kankakee River have been conducted by Westinghouse (1973; 1975), Bergman (1978), Bergman and Hutton (1979), and Bergman et al. (1980). Due to different sampling locations and gear types, comparisons are appropriate only among 1978, 1979, and 1988. Furthermore, 4 periods (dawn, day, dusk, night) were sampled during each 24-hour interval in 1978 and 1979, whereas only two periods were sampled in 1988 (day and night). Thus, only the day and night data collected in 1978 and 1979 was compared with the results of the current study.

Comparisons among taxa that comprised 1.0 percent or more of the catch during at least one of the three study years are as follows:

Relative Abundance (%)

	1978	1979	1988
Darters (all taxa)	6.4	24.0	11.5
Catostomidae (all taxa)	11.8	25.1	32.6
Carp	3.7	7.1	18.0
Cyprinidae (except carp)	38.5	19.0	26.4
Lepomis sp.	6.3	3.9	5.7
Rock bass	1.0	1.8	1.6
Channel catfish	23.1	12.9	1.0
Stonecat	7.0	5.2	0.7

The relative abundance of catostomids and carp was greater in 1988 than has been reported previously, whereas the relative abundance of channel catfish and stonecat was much lower in 1988 than in 1978 or 1979. All other taxa were of similar abundance among the 3 years compared. The mean density of larvae collected in 1988 was comparable to densities in 1978 and 1979:

Mean Density (No./10m^3)

1978	1979	1988
0.62	0.78	0.85

Similarly, Bergman et al. (1980) reported that larval density in the Kankakee River was about 3-fold higher at night than during the day, just as was found to be the case in 1988 (Section 3.1.1).

4.1.2 Horse Creek

Previous ichthyoplankton studies were conducted in Horse Creek during 1972, 1974, 1977, 1978, and 1979 (Westinghouse 1973 and 1975; Bergman 1978; Bergman and Hutton 1979; and Bergman et. al. 1980). Due to the sparse data available in 1972 and 1974, comparisons are appropriate only between the 1977-1979 and 1988 data. Furthermore, several differences in sampling methodologies exist that need to be considered when making such comparisons. In 1977, four replicate samples were collected during the day and at night using a bongo net. In 1978, four replicate night samples were collected using a bongo net. Also in 1978, single samples were collected during four diel periods (dawn, day, dusk and night) using the square-frame sampler that was used in all future studies. In 1979, four replicate samples were collected during each of four diel periods. In 1988, four replicate day and four replicate night samples were collected. The 1977 data is presented as originally reported; whereas, only selected data from 1978 and 1979 (i.e. only day and night diel periods) is used for comparisons.

Comparisons among taxa that comprised 1.0 percent or more of the catch during at least one of the four study years are as follows:

Relative Abundance (%)

	1977	1978	1979	1988
Darters species	16.3[a]	12.9	15.5	4.6
Catostomidae	3.9	36.4	42.6	73.6
Carp	-	0.9	1.4	0.1
Cyprinids	34.0	40.8	33.5	17.4
Lepomis sp.	37.5	-	1.3	2.1
Rock bass	8.3	6.1	4.1	1.2
Smallmouth bass	-	1.7	0.8	0.5

(a) Reported as Percidae

The relative abundance of catostomids in 1988 was much greater than has been reported previously, whereas, all other taxa, except Lepomis sp. were lower in relative abundance in

1988 than in 1977-1979. The mean density of larvae collected in 1988 was two to three times higher in 1988 than in 1977-1979:

Mean Density (No./10m^3)			
1977	1978	1979	1988
3.30	5.48	4.22	10.76

The difference in mean densities is primarily due to the higher density of catostomids in 1988:

	Density (No./10m^3)			
	1977	1978	1979	1988
Darters species	0.54[a]	0.70	0.65	0.47
Catostomidae (all taxa)	0.13	1.99	1.80	7.83
Carp	-	0.05	0.06	0.02
Cyprinids (except carp)	1.12	2.24	1.41	1.97
Lepomis sp.	1.24	-	0.05	0.24
Rock bass	0.27	0.33	0.17	0.13
Smallmouth bass	-	0.09	0.03	0.06

(a) Reported as Percidae

The density of all predominant taxa in 1988, except catostomids, is either lower than or similar to the previous studies.

In 1988, we found that the mean density during the night was more than 60 times higher than during the day. Bergman et al. (1980) reported that the density at night was about 10 times higher than during the day and that the density at dusk was about 30 times higher than during the day.

4.1.3 Survival Study

The survival rate was slightly higher at the Discharge (0.75) than at the Intake (0.68). This difference is probably due to species composition. Lepomis sp. was the only taxa that was common between the two sites and it survived at nearly the same rate at the Intake (0.78) as at the Discharge (0.80). The predominance of Lepomis, with its high survival rate, accounted for the higher survival rate at the discharge.

Even though sample sizes for most taxa and life stages were too small for meaningful analysis, the studies at each site documented high larval fish survival. Survival rates may be even higher than reported, considering that the survival rates were calculated with no correction for collection (i.e., gear-induced) mortality. Cada and Hergenrader (1978) noted a direct relationship between observed mortality and velocity in nets, and it also has been documented that the initial survival of striped bass larvae collected with a 0.5 m, 591 um mesh net ranged from approximately 50 percent at 15 cm/sec (0.5 ft/sec) to 0 percent at 91 cm/sec (3.0 ft/sec) (New York University 1976; O'Connor and Schaffer 1976).

Collectively, the data gathered during the survival studies suggests that approximately two-thirds of the larvae entrained at the Braidwood Station survive passage through the plant. However, no survival data are available for catostomids, one of the most frequently collected taxa (Section 3.1.1).

4.1.4 Dye Studies

An important factor which pertains to entrainment at the Braidwood Station is the proximity of Horse Creek to the intake structure. Studies by Sule and Skelly (1985) showed that Horse Creek is a very important spawning area for shorthead redhorse. They found that approximately 3,000 adult shorthead redhorse were present in a single raceway-riffle area of Horse creek on 30 April 1979. Visual observations and reports from earlier investigators (Westinghouse 1973; Berman and Hutton 1979; and Bergman et. al 1980) have indicated that the water from Horse Creek appears to stay along the plant-side (left) of the Kankakee River. Westinghouse (1973) reported that the makeup water for Braidwood cooling lake may be influenced by the chemistry and temperature of the water in Horse Creek. EA conducted two dye studies to determine the actual path followed by water from Horse Creek after it enters the Kankakee River. Both of the studies were conducted under low flow conditions (1250-1650 cfs); one with the plant pumping and one with the plant not pumping.

It appears that despite the presence of the riffle, Horse Creek contributes to entrainment at the intake. The magnitude of potential effects will largely depend on the species composition, drift densities, abundance, seasonal distribution of ichthyoplankton and size of ichthyoplankton in the Horse Creek drift. The ichthyoplankton and macroinvertebrate entrainment data collected in 1988 suggest that the species composition and abundance of organisms at the intake is comprised of drift from both Horse Creek and the Kankakee River, but is more influenced by Kankakee River drift (see Sections 3.1.1.3 and 3.1.2.3). Entrainment of Horse Creek larvae may be greatest under high flows (riffle submerged) when flows in Horse Creek are fast enough to carry larvae out of Horse Creek into the river. Under low flows (riffle exposed), ichthyoplankton will have a greater chance to stay in the deeper holes in Horse Creek, or fall out of drift in the slack water at the downstream end of the riffle. When the flow in the Kankakee River was 1250 cfs and the flow in Horse Creek was 13.9 cfs, it took the dye plume about 45 minutes to travel approximately 50 meters in Horse Creek, whereas when the flow in the river was 1650 cfs and the flow in Horse Creek was 38.1 cfs, it took the plume about 15 minutes to reach the mouth.

Bergman et al. (1980) speculated that during low flow conditions (<2300 cfs), the exposed riffle channels all water from Horse Creek away from the Intake, thereby minimizing entrainment losses. However, the dye studies we conducted under low flow show that the spatial displacement caused by the riffle is only temporary and that water coming out of Horse Creek is redirected towards the Intake as soon as it reaches the downstream edge of the riffle.

4.2 MACROINVERTEBRATE DRIFT

4.2.1 Kankakee River

Previous macroinvertebrate studies in the Kankakee River have been conducted by Bergman (1978), Bergman and Hutton (1979), and Bergman et. al. (1980). The 1977 study included only natural substrate sampling (Ponar grabs), whereas the 1978 and 1979 studies included both natural and artificial substrate (Hester-Dendy samplers) sampling. Although no previous studies have utilized drift sampling (as was done in 1988), we feel some general comparisons can be made between the artificial substrate sampling in 1978 and 1979 and the drift sampling in 1988. We feel such comparisons are appropriate because artificial substrates depend on the drift as the source of macroinvertebrates to colonize the samplers. The 1988 data are based on macroinvertebrates present in the drift from 19 April through 13 September. These data are compared below with artificial substrate data from the spring and summer exposure periods of 1977 and 1978. The 1977 samplers were retrieved on 25 May (spring) and 1 September (summer), each after a two month exposure period. The 1978 samplers were retrieved on 20 June (spring) and 31 August (summer), each after a two month exposure period. Thus, the time of year for which the comparisons are being made are similar.

Comparisons of the relative abundance of the dominant taxa collected from the Kankakee River in 1978, 1979, and 1988 are as follows:

Taxa	Relative Abundance 1988 (19 APR - 13 SEP)	1979 Spring	1979 Summer	1978 Spring	1978 Summer
Oligochaeta	7.4	0.9	2.2	3.0	2.2
Ephemeroptera(other)	30.0	5.7	10.1	10.2	6.3
Baetidae	16.0	8.3	6.2	6.9	11.3
Heptageniidae	12.5	13.4	24.8	6.7	32.9
Trichoptera (other)	2.4	0.5	1.3	0.5	3.3
Hydropsychidae	1.1	45.9	30.1	4.6	15.9
Simuliidae	0.1	0.4	4.4	39.1	0.4
Chironomidae	17.2	17.9	16.8	26.3	21.3
Other	13.3	13.2	15.5	2.7	6.2

The spring 1978 community was dominated by Simuliidae; in all other years this taxon was uncommon, ranging in relative abundance from 0.1 to 4.4 percent. Other important taxa in 1978 were Rheotanytarsus, Isonychia, Pseudocloeon, and Polypedilum. Mayflies of the family Heptageniidae accounted for one-third of the total number of individuals collected from the Kankakee River in the summer of 1978. This was the highest relative abundance observed for the Heptageniids. The 1979 spring and summer communities were dominated by the caddisfly Cheumatopsyche. Cheumatopsyche and other members of the family Hydropsychidae combined to account for 30.1 to 45.9 percent of the 1979 summer and spring communities, respectively. The abundance of Hydropsychidae (especially Cheumatopsyche) in 1979 was much higher than in 1978 or 1988. Other important taxa in 1979 were Rheotanytarsus, Hydropsyche phalerata, Baetis, Stenonema sp., S. integrum, Dicrotendipes, and Tricorythodes. The 1988 community was dominated by the mayflies, especially Caenis, which was the single most abundant taxa collected and comprised 9.8 percent of the 1988 catch. Collectively, mayflies comprised 58.5 percent of the catch in 1988 which is similar to what was observed in the summer of 1978 when they comprised 50.5 percent of the catch. The mayflies of the family Baetidae had a higher relative abundance in 1988 than in 1978 or 1979. Oligochaetes were also relatively more abundant in 1988 than in 1978 or 1979, whereas chironomids were very similar among the years compared. Other important dominants in 1988 were Ephoron, Hexagenia, Heptagenia maculipennis, Baetis, and Pseudocloeon.

The most obvious differences in relative abundance among 1978, 1979, and 1988 were the lower abundance of hydropsychid caddisflies in 1988 and the greater abundance of "other" mayflies (e.g., Caenis, Hexagenia, and Ephoron) in 1988 than in 1978 or 1979. These differences may be attributable to the difference in sampling methods (i.e., drift nets vs artificial substrate samplers) or to the difference in flows (flows in 1988 were among the lowest on record). Even through the data cannot be compared quantitatively among years, species richness (i.e. number of taxa) of macroinvertebrates collected by the different methods in 1977, 1978, 1978, and 1988 is impressive:

Method	1977	1978	1979	1988
Natural Substrate	158	163	163	-
Artificial Substrate	-	158	146	-
Drift	-	-	-	132

The drift samples in 1988 yielded slightly fewer taxa than either the natural or artificial substrate samples collected in 1977-79.

4.2.2 Horse Creek

Previous macroinvertebrate studies in Horse Creek have been conducted by Bergman (1978), Bergman and Hutton (1979), and Bergman et. al. (1980). Although no previous studies have utilized drift sampling (as was done in 1988), we feel some general comparisons can be made between the artificial substrate sampling conducted in 1978 and 1979 and the drift sampling conducted in 1988.

Comparisons of relative abundance among the dominant taxa collected in 1978, 1979, and 1988 are as follows:

	Relative Abundance				
	1988	1979		1978	
Taxa	(19 APR - 13 SEP)	Spring	Summer	Spring	Summer
Oligochaeta	21.6	5.4	0.6	45.3	1.8
Ephemeroptera(other)	1.4	1.0	0.2	3.4	0.1
Baetidae	7.3	1.6	0.9	0.3	0
Heptageniidae	3.4	5.3	4.3	1.1	9.4
Caenidae	3.8	1.2	2.9	1.9	12.4
Tricorythidae	2.0	18.0	14.3	0	4.8
Trichoptera (other)	2.3	1.4	6.1	1.5	0.8
Hydropsychidae	1.5	3.3	7.7	<0.1	0
Chironomidae	29.2	54.9	57.5	43.9	31.5
Other	27.5	7.9	5.5	2.5	39.2

With the exception of the mayfly family Baetidae and midges in the family chironomidae the relative abundance values in 1988 fall within the range of values reported previously.

Chironomidae and Oligochaeta dominated the Horse Creek benthic community in 1978 and 1988, while Chronomidae and Tricorythidae were the dominants in 1979.

A higher relative abundance of Tricorythidae and Chironomidae was observed in 1979 than in 1978 or 1988. Conversely, Oligochaeta abundance was lower in 1979 than in 1988 or the spring of 1978. The relative abundance of Heptageniidae, Caenidae, and Trichoptera was typically similar among years.

The number of taxa collected during natural substrate, artificial substrate, and drift macroinvertebrate studies in 1977-1979 and 1988 is as follows:

Method	1977	1978	1979	1988
Natural Substrate	76	48	69	-
Artificial Substrate	-	108	103	-
Drift	-	-	-	107

In contrast to what was observed in the Kankakee River, the Horse Creek drift and artificial substrate samples yielded many more taxa than did the natural substrate samples.

4.3 IMPINGEMENT

In 1980-1981, an impingement study was conducted from 1 December through 18 February (CeCo 1981). Data from the 1980-81 study are compared herein with data from a similar time period (4 December - 23 February) during the 1988-89 study. For these similar periods, 31 species were collected in 1980-1981 compared to 42 species in 1988-1989. Pumpkinseed and redear sunfish were reported in 1980-1981 but were not present during the 1988-1989 study. Twenty-two species were common between the two studies. In 1980-1981, a total of 36 impingement collections made during the period 1 December - 18 February resulted in a catch of 466 fish. From 4 December 1988 - 23 February 1989, 34 impingement collections resulted in the collection of 11,705 fish.

Total fish impingement for the period December 1, 1980 through February 21, 1981 was estimated to be 1,201 individuals. The estimated number of fish impinged was 635 in December, 318 in January and 249 through the third week of February (CeCo 1981). Total fish impingement for the period December 4, 1988 through February 23, 1989 was estimated to be 34,065; a 30-fold increase over the previous study. The estimated number of fish impinged was 15,867 in December 1988, 15,468 in January 1989, and 2,720 through the third week of February 1989. The difference in estimated impingement numbers was due to the much greater abundance of gizzard shad in 1988-1989. In the 1980-1981 study, the estimated number of gizzard shad was 4.6 individuals (0.4 percent) compared to 28,957 individuals (85.0 percent) in the total catch for 4 December 1988 through 23 February 1989.

The population of gizzard shad in the Kankakee River in 1988 was the highest recorded since the Braidwood Aquatic Monitoring Program began in 1977 (Larimore and Peterson 1989). The high population in the river corresponds to peak abundance in the Braidwood Cooling Lake. Miller (1989) reported that the 1988 catch of gizzard shad in the cooling lake was the highest ever recorded and also noted that spawning success was excellent. The findings of Miller in conjunction with our observation that gizzard shad was the dominant species in the discharge (see Section 3.1.1.4) suggests that recruitment from the cooling lake may have been the source of the large number of gizzard shad collected in the river by the INHS and subsequently impinged at the Intake. Subsequent studies by Miller (1990) have demonstrated that the gizzard shad population in the cooling lake continues to increase and that recruitment in 1989 was excellent.

5. IMPACT ASSESSMENT

5.1 POTENTIAL IMPACTS TO ICHTHYOPLANKTON

Based on the extrapolations described in Section 3.1.1.8, we estimated that during the 1988 study period, the Braidwood Station entrained 5.8 million larvae and 0.7 million eggs. Under worst case conditions these estimates increase to 11.2 million larvae and 1.0 million eggs. These estimates are compared below to the estimated number of eggs and larvae drifting in the Kankakee River:

	Number			% Intake River	
	Intake				
	Actual	Worst Case	Kankakee River	Actual	Worst Case
Eggs	686,036	995,888	817,320	83.9	121.8
Larvae	5,836,638	11,234,263	37,697,167	15.5	29.8
Total IP	6,522,674	12,230,151	38,514,487	16.9	31.8

Inspection of the above data reveals that the percentage of eggs entrained is anomalously high. Since we know that eggs drift passively and we also know that there was no difference in the lateral distribution of eggs at the upstream transect (see Section 3.1.1.6), it is logical to expect that the number of eggs in the intake should be proportional to the amount of water that the Intake withdraws from the river. For example, even at the plant's maximum pumping rate (50,000 gpm), it uses only about 20 percent of the river flow at low flow conditions (i.e., 500-600 cfs). Therefore we would predict that the number of eggs in the Intake would be less than 20% of the number of eggs in the river. However, as is shown above, the percentage under the actual case is 83.9, while the worst case estimate actually exceeds 100%. There are at least two possible explanations of this anomalous situation; either the number of eggs in the Kankakee River drift is supplemented significantly by the contribution from Horse Creek or spawning is taking place in or immediately upstream of the Intake. Since Horse Creek accounted for less than 50,000 eggs during the entire study period (see Table 3-10), its contribution can not account for the number of eggs observed at the Intake. We conclude therefore that spawning probably took place in the area of the Intake and that some of these eggs were drawn into the Intake. However, we can not rule out the possibility that the high number of eggs at the Intake was caused by some factor we have not considered. Our proposed explanation that the number of eggs is high because of spawning near the Intake is plausible biologically because there is a large, deep slack-water area between the Intake and the riffle near the mouth of Horse Creek (see Figure 3-6). This area probably serves as a spawning area for species that prefer to spawn in areas off the main current (e.g., carp, Lepomis, and many cyprinids). We conclude that egg entrainment may have had an effect on a variety of fish species, but would most likely effect those spawning immediately upstream of the plant. However, any effects will probably be restricted to that portion of the population near the Braidwood Station.

To determine whether the loss of 15.5 to 29.8% of the larvae in the Kankakee River is cause for concern, several factors must be considered: (1) the size of larval population, (2) the percent of that population "at risk", (3) natural mortality rates, (4) the biology and ecology of individual species or taxa, (5) population data on adult fish in the Kankakee River, (6) the representativeness of the 1988 data, and (7) the contribution from the discharge. Each of these factors is discussed below.

Larval Population Size

First it is important to note that the numerical estimate at the upstream transect is based on that portion of the larval community susceptible to collection using drift nets. For taxa that actively enter the drift (e.g., most catostomids, cyprinids, and percids), the estimates we have derived are probably quite reasonable. However, the abundance of species or taxa that rarely or only occasionally enter the drift (e.g., most centrarchids, particularly smallmouth bass and rock bass, ictalurids, and esocids) will be greatly underestimated. Second, the larval population measured at the upstream transect represents only a portion of the larvae in the river because of the contribution from tributaries. For example, in this study we documented that a stream as small as Horse Creek contributed over 4 million larvae, approximately 10% of the number at the upstream transect. In the Illinois portion of the Kankakee, there are six tributaries that are approximately the size of Horse Creek, each of which probably contributes a number of larvae comparable to that from Horse Creek. The Iroquois River, when it joins the Kankakee at Aroma Park, is comparable in size to the Kankakee and undoubted contributes greatly to the larval fish population in the Kankakee. Although larvae from these other sources (except Horse Creek) probably do not materially affect the drift near the Braidwood Station, they do serve to supplement larval fish populations in the Kankakee River and need to be considered.

Population at Risk

As discussed by Goodyear (1977), the percent loss at any fixed point on a riverine system (e.g., at the Braidwood Station), should be adjusted to account for that portion of the population that is not at risk via entrainment. For our purposes, we will limit the area that serves as a potential source of recruitment to that portion of the Kankakee River that lies in Illinois. This distinction is not merely geographical. The Kankakee in Illinois is a meandering, well vegetated stream, with predominantly rocky substrates; whereas, in Indiana, the Kankakee is a straight channelized stream; nearly devoid of vegetation, with sand substrates. These differences in substrate and morphology result in very different fish communities in Illinois compared to Indiana (Brigham et al. 1978, Seegert 1987). The Illinois portion of the Kankakee is approximately 58 miles long. Of this, 25% (14.5 miles) is located downstream of the Braidwood intake and larvae produced here would not be "at risk". Similarly, larvae in the 42% (24.5 miles) of the river upstream of the dam in Kankakee are probably not at risk. Thus, correcting for the proportion of larvae originating outside of the influence of the plant yields the result that .33 (1.0-.25-.42) of the larvae are within the influence of the plant. Therefore, the percent reduction in the total number of larvae produced in the Illinois portion of the Kankakee River, attributable to operation of the Braidwood Station becomes 5.1 (15.5% x .33) under the actual case scenario and 9.8 (29.8% x .33) under the worst case scenario. These values suggest that impacts to the populations(s) as a whole are unlikely.

Natural Morality Rates

Mortality rates are high in early life stages of fish; large numbers of eggs and larvae are produced to compensate for these high rates. Survival rates vary according to life stage (i.e., egg, yolk-sac larvae, postlarvae) and species. Unfortunately, data are available for only a few species. Dahlberg (1979) reviewed this topic and reported mortality rates of 97-98% for northern pike, yellow perch, and white sucker from the egg through the post-larval stage, and >99.9% mortality for walleye during the same period. Mortality during the larval stage only was reported to be 83 and 97% for northern pike and walleye, respectively (Dahlberg 1979). Given the fact that 90% or more of the larvae entrained would die anyway before even becoming juveniles, it seems unlikely that the loss of 5.1 to 9.8% on a system wide basis will have a significant impact. The loss of 15.5 to 29.8% of the local population is not so easily dismissed, however.

Biological Factors

Although we can not assign risk on an absolute basis, it is possible to list and rank species or taxa based on several biological or ecologial criteria (Table 5-1). Inspection of the information presented in Table 5-1 suggests that the groups or species least likely to be affected are: (1) catostomids and gizzard shad which are abundant, fecund, and are entrained less frequently than expected; and (2) centrarchids, esocids, and ictalurids because they are not susceptible to the drift and/or have abundant populations in the river. Cyprinids appear on each side of Table 5-1. In our judgement, high fecundity rates and their abundance suggest that impacts to the common cyprinids of the river (i.e., spotfin shiner, rosyface shiner, sand shiner, and bluntnose minnow) are unlikely. However, impacts to rare or uncommon cyprinids are possible, particularly to those restricted to the lower Kankakee River (e.g. pallid shiner and ghost shiner). Darters are the group most likely to be impacted by Braidwood entrainment because they have relatively low populations to begin with, produce relatively few eggs, and are disproportionately represented in the drift.

TABLE 5-1. COMPARISON OF SPECIES AND TAXA MOST AND LEAST LIKELY TO BE IMPACTED BY ENTRAINMENT

Species or Taxa Most Likely to be Impacted	Species or Taxa Least Likely to be Impacted
1) Those whose abundance is disproportionately high in the entrainment samples: Cyprinids (except carp) *Percina* spp.	1) Those whose abundance is disproportionately low in entrainment samples: Catostomids Gizzard shad
2) Those that enter the drift regularly and produce comparatively few eggs: Most darters	2) Those that are abundant in the river and/or have high fecundity rates: Most cyprinids Many catostomids and centrarchids Gizzard shad
3) Those that are rare or uncommon and largely restricted to the lower Kankakee: Pallid chub Ghost shiner Mimic shiner	3) Those that rarely enter the drift: *Micropterus* spp. Rock bass *Esox* spp. Ictalurids

The pallid shiner (chub) is an endangered species whose distribution was originally thought to be restricted to a small portion of the Kankakee River near the Braidwood Station (Skelly and Sule 1983), but has since been shown to be more widespread, though apparently still restricted to the lower Kankakee (EA 1989 [Appendix E]; EA 1990). Our impingement studies showed that a number of pallid shiners were impinged from late April through early June 1989 suggesting that some pallid shiner eggs and larvae could have been entrained in 1988. The number can not be quantified, however, because the larvae of this species are undescribed.

Although little is known about the reproductive biology of the pallid shiner, it seems likely that the populations occurring several miles upstream of the plant (see Appendix E) represent spawning (breeding) populations that are physically separate from those near the Braidwood Station. As such, larvae from these upstream populations are probably not at risk via entrainment.

Comparisons to Field Studies

Any losses in the 1988 cohort will not be detectable until 1989 and beyond. Field data collected in 1989 does not reveal any evidence that species or groups near the Braidwood site were impacted by the rate of entrainment that prevailed in 1988. The Illinois Natural History Survey (INHS) has been sampling adult fish populations in the Kankakee River near Braidwood annually since 1977. Their data are still in draft form but their 1989 total catch was the 4th highest to date (by number) and the 3rd highest to date (by weight). In 1989, we (EA 1989, Appendix E) conducted a seining survey of the Kankakee River to determine the abundance and distribution of the pallid shiner. Although the abundance of other species was not quantified, we noted that the river contained an exceptionally rich fish fauna and that the abundance of many species was extremely high. Importantly, we also documented that the pallid shiner was both more common and widespread than previously thought. Collectively, the results of the two 1989 field studies do not suggest any impacts to the 1988 year class. To the contrary, our data and that collected by the INHS suggest that 1988 produced exceptionally strong year classes for a variety of species: gizzard shad, ghost shiner, mimic shiner, golden redhorse, rock bass, and smallmouth bass.

Representativeness of the 1988 Data

1988 was a year that produced record low flows on many midwestern streams. The Kankakee was no exception as monthly average flows were <1000 cfs for the period June through September (Table 5-2). These extremely low flows approximated worst case conditions in terms of the percent of the river withdrawn by the plant. Therefore, we conclude that entrainment losses in other years will probably be considerably less than those

TABLE 5-2. COMPARISON OF MEAN MONTHLY FLOWS FOR THE PERIOD APRIL THROUGH SEPTEMBER, 1977-1988.

Year	Apr	May	Jun	Jul	Aug	Sep
1977	6,214*	4,820	1,427	1,192	3,410	7,144
1978	12,180	8,455	5,465	3,285	1,225	867
1979	14,160	7,740	3,351	3,112	3,989	1,250
1980	8,850	3,899	10,070	1,290	1,398	3,472
1981	9,038	15,810	12,510	6,809	5,775	5,141
1982	10,340	5,752	5,684	4,013	2,331	1,173
1983	11,680	14,320	4,536	4,190	1,380	914
1984	9,309	11,210	6,695	2,610	1,323	832
1985	11,810	3,232	2,602	1,477	2,102	1,462
1986	4,353	7,370	8,941	6,268	1,655	1,321
1987	4,965	7,270	6,179	2,272	1,692	1,580
1988	9,074	2,852	997	467	451	729
Range	4,353-14,160	2,852-15,810	997-12,510	467-6,809	451-5,775	729-7,144
1988	9,074	2,852**	997**	467**	451**	729**

* Data from USGS gaging station at Wilmington.
** The 1988 average was the lowest among the last 12 years

observed in 1988. Furthermore, even though flow conditions in 1988 were representative of worst case conditions, the station did not pump nearly as frequently as we assumed in our worst case estimate.

Contribution from the Discharge

We determined that 1.7 million ichthyoplankton were discharged back into the river (see Table 3-15), 75% of which were alive (see Section 3.1.1.5). Therefore, about 1.3 million larvae are returned to the Kankakee River to offset the losses at the Intake.

5.2 POTENTIAL IMPACTS TO MACROINVERTEBRATES

Based on the extrapolations described in Section 3.1.1.8, we estimate that the Braidwood Station actually entrained 50 million organisms, which represents 7.6% of the drift during the study period. Under worst case conditions, the plant would have entrained 124 million organisms or 18.6% of those in the drift. Much less data are available to determine whether these entrainment levels may affect macroinvertebrate populations in the river. For example, there are no followup field data with which to make comparisons and there are no estimates regarding the natural mortality rates of individual taxa. However, as was done for the fish larvae, it is reasonable to assume that only about one-third of the mainstem Kankakee River macroinvertebrate population is at risk, and that contributions from various tributaries supplement the population in the mainstem. For example, our "ballpark" estimate of the contribution from Horse Creek was eight million organisms.

If the actual and worst case values are adjusted to account for that portion of the population at risk, it appears that the resultant values (2.5% - 6.1%) are low enough that, when coupled with contributions from the various tributaries, impacts to the population as a whole are unlikely. Local impacts are more likely but data are insufficient to determine whether they might be significant. Since mayflies accounted for approximately half the macroinvertebrates entrained, they would be the taxa most likely to be impacted.

5.3 POTENTIAL IMPACTS TO JUVENILE AND ADULT FISH

To determine whether the loss of 53,000 adult and juvenile fish from the Kankakee River is cause for concern, several factors must be considered: (1) the percent of that population "at risk", (2) the biology and ecology of individual species, (3) the size of the fish being impinged, and (4) population data on adult fish in the Kankakee River.

We estimate that, at the most, about 38 percent of the fish population in the Illinois portion of the Kankakee River is at risk of actually being impinged at the Braidwood Station. This is the population in the 22-mile section of the river between the dam in Wilmington and the dam in Kankakee. Thus, the population in well over half the river will be completely unaffected by operation of the Braidwood Station. Furthermore, a high, but unkown, percentage of the fish in the Wilmington pool will rarely, if ever, be near enough to the Braidwood Station to be impinged.

Of the 53,111 fish estimated to be impinged, 69% (36,608 fish) would be gizzard shad. This species is very prolific; Bodola (1964) found that production of 0.5 million eggs per female was not uncommon. Furthermore, 78 percent of the gizzard shad loss occurred from early December through early February. Gizzard shad impingement is usually highest during the winter at midwestern power plants (EA 1987, 1988), probably as a result of impinging winter killed individuals (Trautman 1981). Thus, the impingement of gizzard shad at Braidwood is biological insignificant. Rock bass, the second most frequently impinged species, is also prolific. The Wisconsin DNR describe it as "a very prolific fish with a tendency toward overpopulation" (WDNR 1973). The 5000 rock bass estimated to be impinged at the Braidwood Station represent the average egg production from a single adult female (Becker 1983).

It should also be noted that gizzard is not the only species that is subject to winter kill or the only one impinged in poor condition. Biologists working on the Mississippi River reported that impinged fish at the Quad-Cities Station showed a higher rate of afflictions (i.e. parasites, disease, etc.) than did fish caught by standard sampling techniques (e.g., electrofishing and netting) (LMS 1987). Biologists on the Hudson River noted that impinged fish had lower condition (k) factors than did fish caught by conventional methods (Cannon and Lauer 1976). Hlohowskyj et al (1988) examined fish impinged at two Lake Erie power plants and concluded that 30% of all impinged fish had terminal fungal and/or parasitic infections. They also found that at least 40% of all impinged fish were dead prior to being impinged and that many fish exhibited signs of post-spawning mortality or natural autumn mortality. Only 20% of the fish examined were outwardly healthy. These findings by other investigators suggest that a large percentage of the fish impinged at the Braidwood Station were already dead or would have died regardless of being impinged at the Intake. The low average velocities we measured at the Intake ($\sim$0.35 ft/sec) support this hypothesis as healthy fish should be able to avoid impingement at velocities this low.

The estimated impingement losses are also tempered by the fact that more than 90% of the fish lost (except for minnows) are either YOYs or juveniles. For example, 90% of the impinged rock bass were <90 mm and 93% of the impinged smallmouth bass were <130 mm. Thus, most of the fish being impinged by the Braidwood Station are small individuals that have naturally high mortality rates due to predation and other factors. Also, the comparatively high rates of impingement for juvenile smallmouth bass and gizzard shad are the result of exceptional year classes for these species. In most years, impingement rates of these species will probably be much lower.

Finally, it is reasonable to expect that if impingement by the Braidwood Station was adversely affecting fish populations, then these impacts would be manifested in lower catches during field studies conducted in 1989 near the Braidwood Station. Prelimininary data collected by the Illinois Natural History Survey show that the 1989 catch near the Braidwood Station was the 4th highest to date (out of 12 years) by number and the 3rd highest to date in terms of biomass. Catches of juvenile smallmouth bass and golden redhorse were especially high in 1989 reflecting a strong 1988 year class for these species. These high catches are not consistent with the hypothesis that impingement by the Braidwood Station significantly reduces fish populations. Other field studies conducted in 1989 also showed that the Kankakee River near the Braidwood Station possesses a diverse and abundant fish fauna (EA 1989, Appendix E).

In summary, we do not believe that the loss of 53,000 fish will have an appreciable impact on fish populations in the Kankakee River because:

(1) much of the population is not at risk;
(2) it is a small number compared to the total fish population in the river;
(3) more than two-thirds of this number is composed of gizzard shad;
(4) of the game fish collected, almost all were young-of-the-year or juveniles;
(5) no impacts were detected in either of the 1989 adult fish field studies conducted near the site;
(6) the high impingement rates for gizzard shad and juvenile smallmouth bass reflect unusually high numbers of these species in the area; and
(7) many of the fish impinged were probably already stressed and/or in poor condition and would not have survived anyway.

Although we do not believe impacts will occur to the fish population as a whole or to common species, it is impossible to assess whether impingement losses may affect the population of the endangered pallid shiner. Studies we conducted in 1989 (Appendix E) showed that the pallid shiner is definitely more widespread and possibly more abundant than previously thought. However, data are insufficient to determine its population size. The fact that pallid shiners were impinged only from 16 April to 10 June suggests that they may be vulnerable for only a short portion of time each year. However, this period probably corresponds to when it is getting ready to spawn because some of the females impinged were gravid and several of the males collected during our late May and early June field study were tuberculate (EA 1989). Based on these facts and considering when it spawns in the southern part of its range (Clemmer 1980), we conclude that pallid shiners in the Kankakee River probably spawn in late May or June. It is possible, therefore, that impingement may affect that portion of the pallid shiner population that resides near the Braidwood Intake.

However, the populations found several miles upstream of the Intake probably represent separate breeding populations (physically separate not genetically separate). If this hypothesis is correct, these upstream populations probably will not be affected by operation of the Braidwood Station.

Finally, we suspect that the population of pallid shiners in the Kankakee River is higher than previously thought, but we simply do not have enough information to assess accurately whether the estimated loss of 73 adults will affect this species.

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